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National Defense Research Institute

Annual Report

Contract Year 1987

November 15, 1986–November 14, 1987

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For a number of years, The RAND Corporation has engaged in research and analysis of major national security issues for the Office of the Secretary of Defense (OSD). Sponsoring elements within OSD have included the Under Secretary of Defense for Policy, the Assistant Secretary of Defense (Force Management and Personnel), the Defense Advanced Research Projects Agency, and the Director of Net Assessment. In 1984, the Under Secretary of Defense for Research and Engineering asked RAND to gather its OSD-sponsored research programs into a single Federally Funded Research and Development Center (FFRDC). The new center—the National Defense Research Institute (NDRI)—was to serve OSD, the Organization of the Joint Chiefs of Staff (OJCS), and other defense agencies.

In creating NDRI, the Department of Defense and The RAND Corporation incorporated several key characteristics of previously established FFRDCs that had been found to yield advantages in conducting research in support of policymaking:

- Because an FFRDC is established under a renewable multiyear contract, it would provide a context within which OSD and RAND could work together to build continuity of expertise. Instead of initiating projects on the basis of passing interests, coherent lines of research would be developed that would address the sponsoring agency's long-term challenges and build on the Institute's strength. Funds would be earmarked for developing and sustaining institutional capabilities, such as databases, analytical facilities, and sophisticated models, that are essential to addressing enduring policy issues. The commitment to long-term investments in research capital would help in attracting and retaining a high-quality research staff. Continuity of expertise would also help make RAND a more flexible resource for OSD, allowing the experience developed within the center to be brought to bear more readily on special questions requiring rapid responses.
- Because FFRDC oversight and guidance would be carried out at a high level within the sponsoring

organization, OSD and RAND would be motivated to encourage research on broad, fundamental policy questions with far-reaching implications. High-level oversight would also help to bridge institutional barriers within OSD and promote a comprehensive, multidisciplinary view of important issues.

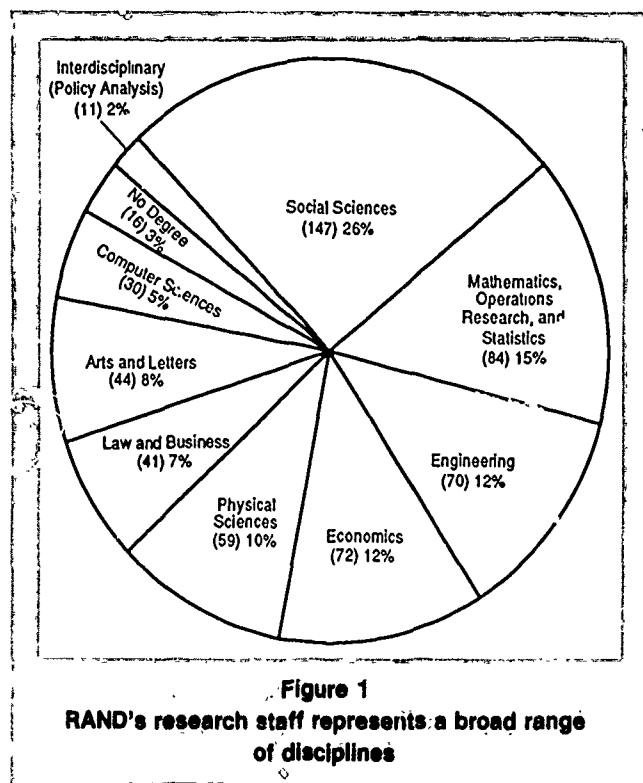
- Because Congress would provide most of the FFRDC's funding through a single program element in the defense budget, the reactions of OSD's sponsoring components to the findings of specific studies would be separated from funding decisions. This would enhance NDRI's independence and objectivity.

THE RAND SETTING

The RAND environment is particularly suited to fulfilling an FFRDC's potential. RAND is a private, nonprofit institution with a 40 year history of work on issues relating to the national security and public welfare of the United States. Since its founding, RAND has become synonymous with a distinctive approach to analysis of public-policy issues. The RAND approach includes the following elements. (a) selection of consequential and complex problems; (b) careful review of the problem statement and, often, a redefinition of the problem itself; (c) a systematic and interdisciplinary approach; (d) independent and objective analysis; (e) breadth and rigor in every phase of research, and (f) policy-relevant conclusions explicitly circumscribed by the limits of the analysis. RAND is also well known for its development of new scientific and strategic-planning methods, including methodologies for thinking about trends, future needs, and future opportunities.

NDRI draws its researchers from RAND's staff of 580 professionals trained in a broad range of disciplines (see Fig. 1). RAND personnel are affiliated with departments (see Fig. 2), which are responsible for hiring and professional development and which promote collegial interactions among researchers with similar backgrounds. About 90 percent of RAND's staff work at corporate headquarters in Santa Monica, California, the remainder are based at RAND's Washington office.

The RAND staff is supplemented by roughly 600 consultants who contribute over 100 person-years of work annually.



NDRI research benefits from institutional expertise accumulated in a variety of policy areas addressed by RAND's five research elements (see Figs. 2 and 3). RAND staff working on NDRI research are regularly in contact with staff members working for other divisions of the Corporation and in many instances can draw on their own experience on projects in the other divisions.

Most notably, NDRI can draw on the methods and findings of research in two other defense-related FFRDCs—Project AIR FORCE and the Army-sponsored Arroyo Center. All three FFRDCs perform analyses of international security, evaluations of strategy and tactics, research on defense applications of technology, and assessments of the management of defense resources.

Project AIR FORCE was the first FFRDC founded at RAND. Indeed, it predates the Corporation itself, having been established (as Project RAND) in 1946. Over the years, Project AIR FORCE has conducted pioneering studies on continental air defense, strategic force modernization options, the contribution of tactical air systems to defending Western Europe, and ways of improving combat support operations to increase war-fighting capabilities.

The Arroyo Center is the U.S. Army's sole FFRDC. Located at RAND since 1984, the Arroyo Center has provided the Army with independent studies and analysis centering on an evolving set of related themes. In 1987, the focus was on enhancing conventional forces in central Europe. Building on this NATO focus, the Center is now turning its attention to future Army roles and missions worldwide.

Project AIR FORCE and the Arroyo Center complement NDRI research in several ways:

- They provide a ready source of expertise in Army and Air Force problems and practices.
- They develop analytical tools and databases of common utility.
- They explicitly collaborate with NDRI in some research projects.

NDRI research further benefits from lessons learned in defense-related work conducted at RAND outside the three FFRDCs. This research is administered by RAND's National Security Research Division, which also houses NDRI and is headed by RAND Vice President and NDRI Director Michael D. Rich. In 1987, the sponsors of RAND's non-FFRDC work on national security included the intelligence community, the Department of Energy's Sandia National Laboratories, the Carnegie Corporation, the Pew Memorial Trusts, the National Council for Soviet and East European Relations, and the Smith-Richardson, Ford, and Weingart foundations.

NDRI projects sometimes also draw on experience gained within RAND's Domestic Research Division, and there are occasional examples of explicit collabora-

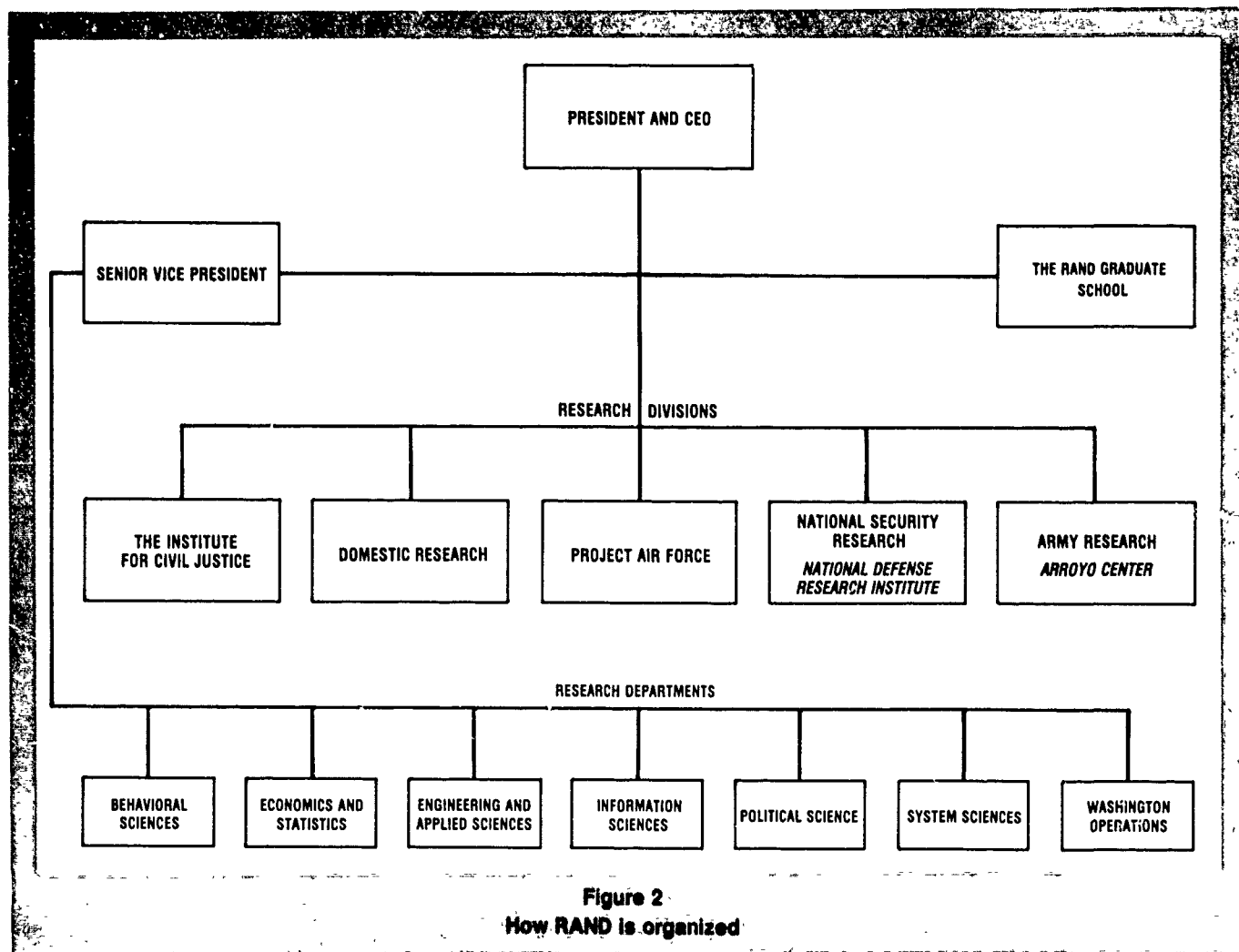


Figure 2
How RAND is organized

tion here, too. The Domestic Research Division addresses problems in health care, criminal justice, education, labor, immigration, and other domestic policy areas. RAND's fifth research element—the Institute for Civil Justice—conducts research on the efficiency and equitability of the administration of civil justice in the United States.

The synergism achieved through collocating research and education is widely recognized. Education and training have always been important aspects of RAND's public service mission. In 1970, the educational role was formalized through the establishment of the RAND Graduate School for Policy Studies, which

offers an innovative, accredited program leading to a Ph.D. in policy analysis. The School recruits students with Master's degrees or research experience, and analytical work on RAND projects is a degree requirement. These students bring fresh approaches to tackling research problems and are keenly sought by project leaders. The RAND Graduate School operates two research centers jointly with the University of California, Los Angeles: the Center for the Study of Health Policy and the Center for the Study of Soviet International Behavior. The latter is housed within RAND's National Security Research Division and is an important source of expertise for NDRI research on Soviet policy.

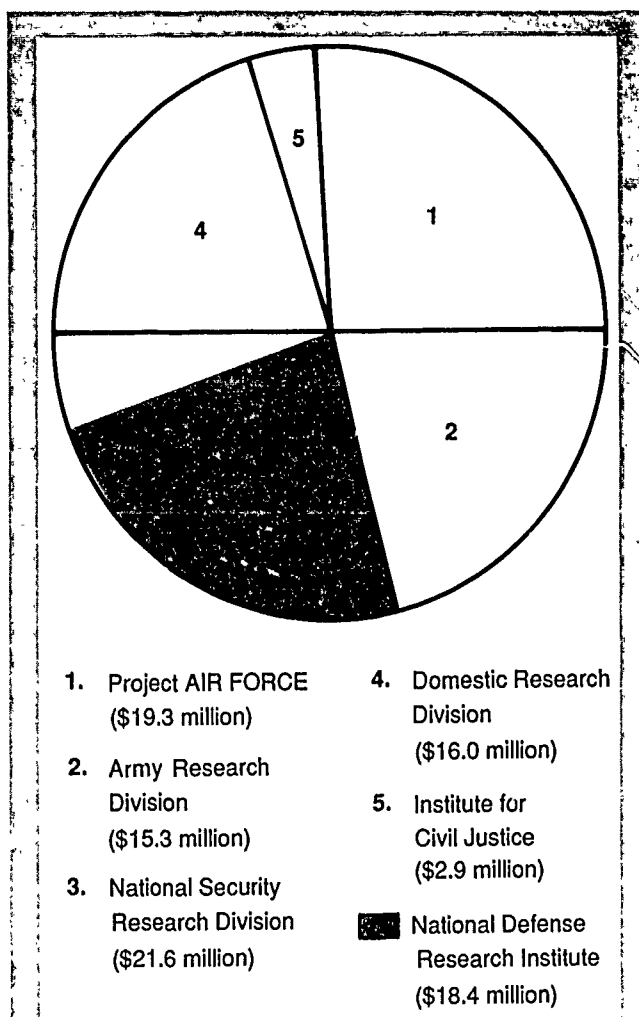


Figure 3
RAND revenues by division (fiscal year 1987)

NDRI RESEARCH THEMES AND DIRECTIONS

The NDRI research agenda is developed in cooperation with OSD and OJCS through the Defense Advisory Group (DAG), which also provides continuing guidance and oversight to NDRI. The DAG comprises ten DoD policymakers (see Table 1), nine from various components of OSD and one from the Organization of the Joint Chiefs of Staff. The DAG is charged with establishing multiyear objectives, evaluating the research effort, setting the FFRDC's annual program element request in the DoD budget, and allocating that core funding among the components represented.

Table 1
DEFENSE ADVISORY GROUP
June 1988

Dr. Robert Costello (Chairman), Under Secretary of Defense for Acquisition
(Vacant), Under Secretary of Defense for Policy
Mr. Grant Green, Assistant Secretary of Defense (Force Management and Personnel)
Mr. Stephen Duncan, Assistant Secretary of Defense (Reserve Affairs)
Mr. Jack Katzen, Assistant Secretary of Defense (Production and Logistics)
Dr. Gordon A. Smith, Assistant Secretary of Defense (Command, Control, Communications, and Intelligence)
Dr. David S. C. Chu, Assistant Secretary of Defense (Program Analysis and Evaluation)
Mr. Raymond S. Colladay, Director, Defense Advanced Research Projects Agency
Mr. Andrew W. Marshall, Director, Net Assessment
Vice Adm. John A. Baldwin, Jr., Director, Plans and Policy, Organization of the Joint Chiefs of Staff
Col. John P. Wilhelm, USAF, Executive Agent

The following held DAG positions during part or all of contract year 1987:

Richard P. Godwin (Chairman), Under Secretary of Defense for Acquisition
Fred C. Iklé, Under Secretary of Defense for Policy
Chapman B. Cox, Assistant Secretary of Defense (Force Management and Personnel)
James H. Webb, Assistant Secretary of Defense (Reserve Affairs)
Donald C. Latham, Assistant Secretary of Defense (C³I)
Robert C. Duncan, Director, Defense Advanced Research Projects Agency
Vice Adm. Powell F. Carter, Jr., Director, Joint Staff, Organization of the Joint Chiefs of Staff
Dr. Costello began the 1987 contract year as Assistant Secretary of Defense (Production and Logistics). Dr. Duncan still plays an important role in NDRI oversight as Director, Defense Research and Engineering.

NDRI's current research agenda is largely oriented toward contributing to the resolution of three key defense policy questions:

1. What are the most important national security challenges facing the United States today and over the next 20 years, and what policy alternatives might meet those challenges?
 - a. How do political and economic trends in the Soviet Union and the Third World impinge on the potential for global and regional conflict?
 - b. What are the security implications of strategic and conventional arms control agreements that seem to be driven largely by political forces?
2. How can the United States counter the Soviet military threat in an era of tightening resource constraints?
 - a. How can the United States improve its planning of strategy, operational art, and tactics?
 - b. How can the United States exploit its technological advantage to produce more effective weapon systems?
 - c. How can force modernization and management be made more efficient?
3. What steps ought to be taken in peacetime to ensure that U.S. forces are ready to fight effectively in war?
 - a. How should the uncertainties inherent in wartime be considered in planning for crisis and conflict?
 - b. How should wartime uncertainties be considered in planning for force deployment and support?
 - c. What can be done to enhance the readiness of the personnel force?

These questions do not exhaust the issues taken up within NDRI, but they are indicative of the policy-level objectives of much of the research effort. The structure of that effort is evolutionary, not static. Within the past two years, NDRI has placed more emphasis on force employment, weapon acquisition, and combat support issues and on defense applications of advanced computer sciences. In the coming year, NDRI will be working with the DAG to expand the Institute's research agenda regarding the economic and political burdens facing General Secretary Mikhail Gorbachev in the Soviet Union. Another objective is to devote

more effort to research supporting the formulation and evaluation of global military strategies.

RESEARCH PROGRAMS

The central questions guiding the NDRI research agenda are being addressed variously by the Institute's eight formal research programs. These programs provide the long-standing research foci required to maintain continuity of expertise and responsiveness to shifts of emphasis in NDRI's research agenda. The programs are the basis for the administrative organization of research within NDRI (see Table 2), and the structure of this report follows that organization. The eight programs are as follows:

- The International Economic Policy Program examines issues at the interface between national security and international trade, finance, and development.
- The International Security and Defense Policy Program analyzes the implications of future geopolitical environments for U.S. national security interests and defense objectives, and considers issues related to strengthening the defense policy formulation process.
- The Strategy Planning and Assessment Program, and the RAND Strategy Assessment Center within it, emphasize integrative assessment of alternative national strategies, military balances, force structures, and arms control agreements.
- The Force Employment Program assesses the potential combat effectiveness of alternative force structures, new weapon systems, and novel operational concepts.
- The Applied Science and Technology Program supports the development of innovative device and system concepts to improve military operations and studies how those concepts can be effectively implemented on the battlefield.
- The Information Processing Systems Program conducts research on knowledge-based simulation, intelligent databases, expert systems, and related topics. The objectives are to advance the state of the art in those areas and to develop prototype tools and techniques for application to defense-related decisionmaking under uncertainty.

- The Acquisition and Support Policy Program investigates opportunities to improve the force modernization process and develops means of accounting for wartime uncertainty in combat support planning.

Table 2
NDRI MANAGEMENT
May 1988

Michael D. Rich
RAND Vice President and NDRI Director
Eugene C. Gritton
RAND Deputy Vice President and NDRI Deputy Director
Mary E. Morris, Assistant for Operations
Donald Palmer, Representative at the Pentagon

Research Programs

INTERNATIONAL ECONOMIC POLICY

Charles Wolf, Jr., Director

INTERNATIONAL SECURITY AND DEFENSE POLICY

Michael D. Rich, Director (acting)
Brian M. Jenkins, Associate Director
James A. Winnefeld, Associate Director

STRATEGY PLANNING AND ASSESSMENT

Paul K. Davis, Director
Bruce W. Bennett, Associate Director
William L. Schwabe, Associate Director

FORCE EMPLOYMENT

Dean A. Wilkening, Director
Bruce W. Bennett, Associate Director

APPLIED SCIENCE AND TECHNOLOGY

Eugene C. Gritton, Director

INFORMATION PROCESSING SYSTEMS

Iris Kameny, Director

ACQUISITION AND SUPPORT POLICY

John L. Birkler, Director

DEFENSE MANPOWER RESEARCH CENTER

Glenn A. Gotz, Director
David W. Grissmer, Deputy Director

Russell D. Shaver was director of the Force Employment Program during contract year 1987. He was succeeded by Dean Wilkening early in 1988.

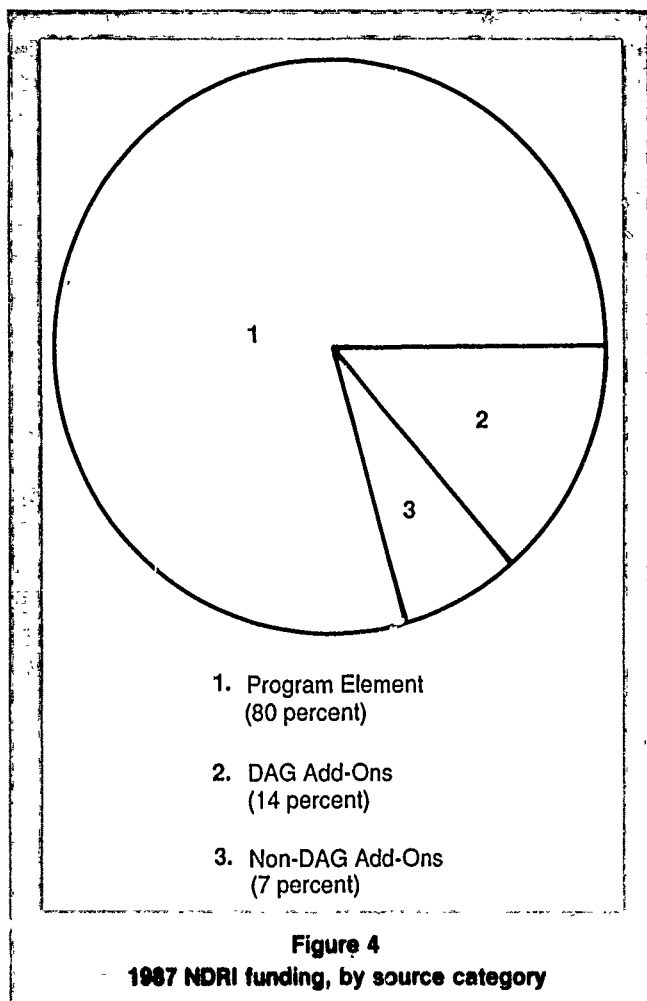
- The Defense Manpower Research Center assesses whether current manpower policies will economically provide enough sufficiently skilled, experienced, and trained personnel to realize the capabilities of the military assets judged necessary to counter evolving threats to U.S. national security.

The goals of the programs and their achievements during 1987 are discussed in detail in Sections II through IX of this report. While each of the programs concentrates on its own set of closely related research areas, the programs address NDRI's principal research questions cooperatively and synergistically. For instance, improving the evaluation of strategy and tactics is being addressed by the Force Employment, Information Processing Systems, and Strategy Planning and Assessment programs. Arms control is a concern of four programs: International Security and Defense Policy, Strategy Planning and Assessment, Force Employment, and Applied Science and Technology.

The programs carry out their research in the form of sponsored projects and, to a lesser extent, in the form of Research Support activities. The following sections explain project funding and development within NDRI and the role of Research Support.

SPONSORED RESEARCH PROJECTS

Projects may be funded in any of three ways (see Fig. 4). A sponsor may allocate a part of its share of the annual program element FFRDC funding. It may supplement its share of the core funding by adding funds of its own. Or funds may come from an agency or office not represented on the DAG, provided that the research being funded draws on expertise uniquely available at RAND, complements ongoing research, and does not delay work already scheduled. Non-DoD sponsorship arrangements must be approved by the DAG, RAND, and the prospective sponsor. In 1987, non-DAG sponsors were the Strategic Defense Initiative Organization, the Assistant Secretary of Defense (Health Affairs), the Defense Communications Agency, the Federal Emergency Management Agency, and the Department of State. Neither NDRI nor any other element of RAND performs proprietary work for private-sector firms.



Project development is a highly interactive process that takes place throughout the year. Specific research projects (40 were begun in contract year 1987) may be recommended by the DAG, by sponsoring offices, or by RAND; most emerge out of extensive discussions among the prospective sponsor, other interested offices, and RAND. The discussions are often informed by exploratory research funded through Research Support and carried out at the initiative of individual researchers within NDRI's programs.

Projects are selected by applying criteria based on the special characteristics of FFRDC and RAND research. The issue must be considered important by the policymakers in the DAG, and it must be amenable to

objective analysis. Balance is sought between projects whose success is likely and those with higher risk of failure—but higher potential payoff. Single-theme, quick-response projects that draw largely on previous work are accepted, but care is taken to keep the emphasis on the more cross-cutting, longer-term studies that exploit the FFRDC's special features and advantages. A premium is placed on projects offering opportunities for innovation and building research capital, for addressing questions with long-term implications, for capitalizing on past RAND research, and for complementarity with current RAND research. Finally, consideration is given to the availability of expertise and to RAND's comparative advantage in addressing the issue.

Some projects are cosponsored to ensure that the research responds to multiple policy interests. In other cases, different OSD elements sponsor complementary projects addressing various aspects of broad problem areas, enriching individual projects and providing a basis for integration and well-rounded evaluation of major policy alternatives.

The following examples illustrate the specific ways in which projects address NDRI's major research questions, they also indicate the character of the research efforts passing the selection criteria.

1. Military implications of political trends.
 - a. Soviet Union and Third World.
 - Development of consistent estimates of gross national products, military capital stocks, and military spending of 15 key countries between 1950 and 2010 for the national Commission on Integrated Long-Term Strategy. The first phase of this work was reflected in the Commission's report, *Discriminate Deterrence*.
 - Projection of trends in the Nicaraguan security threat in the event of the failure of the resistance to overthrow the Sandinista regime. A conference on the Nicaraguan resistance was funded from Research Support in collaboration with

Project AIR FORCE and the Arroyo Center.

b. Arms control.

- Assistance in identifying and analyzing new initiatives for conventional arms control in Europe. This work builds on related studies in all three of RAND's national security FFRDCs.
- Assistance in developing a protocol for inspections to be carried out under the Intermediate-Range Nuclear Forces (INF) treaty.

2. Countering the Soviet military threat.

a. Strategy and tactics.

- Development of the RAND Strategy Assessment System (RSAS), an integrated set of computer programs structured like a war game to facilitate setting up and conducting strategy analyses for hypothetical conflict situations. At the end of the year, the fully operational global version of the RSAS was being readied for installation in a number of government offices.
- Assistance in the formulation of a coherent approach to hold Soviet relocatable targets, e.g., mobile missiles, at risk. Three OSD elements have joined in sponsoring this project.

b. Weapon systems.

- An evaluation of the use of high-power microwaves for suppressing air defenses in deep operations by attack helicopters, and of the susceptibility of deep-strike submunitions to microwave and laser weapons (undertaken in collaboration with Project AIR FORCE).
- Definition of conceptual ground combat vehicle systems that integrate disparate advanced technologies for improving armored-vehicle and crew survivability and for enhancing antiarmor capabilities.

c. Force modernization.

- A review of the acquisition strategy for the B-2 advanced-technology ("stealth") bomber. Three OSD elements were

involved in the initiation and execution of this congressionally mandated study.

NDRI project staff briefed the results to the Secretary of Defense and other senior policymakers.

- A comparison of U.S. marginal costs of strategic defense elements with Soviet marginal offensive-force costs.

3. Peacetime activities to improve readiness.

a. Accounting for uncertainty in planning for conflict.

- An assessment of the balance of military power between NATO and the Warsaw Pact in central Europe, employing multi-scenario analytic war gaming.
- Development and application of techniques to allow explicit representation of expert knowledge in conflict simulations, making the results of the simulations more readily intelligible to military analysts and more easily usable in training.

b. Accounting for uncertainty in planning for combat support.

- A review of the ability of DoD's physical distribution system to function in wartime. Two OSD components and all of the military services were involved in initiating this broad assessment.
- An examination of how planning and management of wartime logistics resources by the Unified Commands is to be linked to their planning and management of combat operations.

c. Personnel force readiness.

- Prediction of Reserve force experience profiles under alternative compensation scenarios, for input to the Quadrennial Review of Military Compensation.
- Estimation of the relative cost-effectiveness of different types of recruiting resources for increasing the supply of high-quality enlistees.

4. Other research questions.

- An assessment of expanding the use of the military in interdicting the flow of

narcotics into the United States.

- An examination of the economic implications of export subsidies granted by Western governments to their industries.

Some of these projects are already complete and are discussed in RAND publications summarized in this report. Such publications are the principal means by which RAND makes its research results available for full utilization and review by the relevant policy and professional communities. RAND publications are also made available to the general public, consistent with security considerations. In contract year 1987, NDRI issued 30 publications reporting the results of its research. Oral briefings are another way of communicating research results and are particularly useful for interim findings and quick communication of final results and for promoting a ready exchange of views. Publications and selected briefings are listed in the following sections.¹

RESEARCH SUPPORT

NDRI uses a small portion of its budget to support nonproject activities intended to help the FFRDC achieve its full potential. Those activities include planning, developing, and managing the overall NDRI research program and conducting exploratory research in support of formulating new projects. NDRI's exploratory research funding provides the opportunities and incentives for staff members to pursue new ideas in enough depth to determine whether there is something worth following up in more detail. Such efforts are essential to innovation, and many of RAND's most important contributions have been initiated in this fashion.

Research Support also allows NDRI to directly assist its sponsors outside the formal project structure, particularly where speed of response is important. Direct

assistance efforts, of which there were over a dozen in 1987, build on staff experience obtained through the Institute's research projects and often entail synthesizing and integrating diverse lines of research. For instance, at the request of the Under Secretary of Defense for Policy, NDRI conducted several quick reviews of the political and legal implications and verification prospects of various arms control treaty provisions. NDRI contributed to a submittal on the aging personnel force by the Assistant Secretary of Defense (Force Management and Personnel) to the Defense Resources Board; NDRI's contributions drew on staff experience in occupational management and personnel force projection. On another occasion, OJCS asked NDRI to perform a quick review of a DoD methodology for assessing damage to strategic mobile targets, the review, a reformulation of the methodology, and coordination of the new approach with relevant DoD staff were completed within one month.

Finally, Research Support is employed to maintain the research infrastructure that facilitates efficient execution of the broad variety of projects within the Institute. That infrastructure includes databases on strategic targeting, orders of battle, weapons effects, and threat characteristics, and models of force employment, logistics, and cost analysis. It also includes support for enhancing staff expertise in areas useful to continuing lines of research. Elements of the research infrastructure receiving support during 1987 include the following:

- The Military Operations Simulation Facility, which maintains a wide variety of robust models and databases using extensive and powerful graphics display media. Because the facility is also funded by Project AIR FORCE and the Arroyo Center, economies of scale are obtained, along with useful synergistic interactions among analysts working for the three sponsoring organizations.
- Databases chronicling terrorist and terrorist-related incidents. These contain textual descriptions and coded variables for 5500 incidents over the last 20 years. The databases are updated through special subscription services, and NDRI

¹Publications are available from the RAND Publications Department. Presentation of a briefing can be arranged through NDRI, a full list of available briefings can be obtained from the Institute.

itself monitors over 90 journals and newspapers, many of them foreign.

- Seminar series to enhance the capabilities of RAND's technical staff. For example, Research Support funds have helped support a continuing series of talks on the analysis of technological issues related to sensor systems. The seminar has built on experience gained from RAND projects, supplemented by speakers from other organizations.

Other examples of Research Support activities are given in the following sections.

CONCLUSION

In founding the National Defense Research Institute, OSD envisioned a valuable addition to DoD's research

assets: an FFRDC, dedicated to the independent, objective analysis of complex, long-term security issues, drawing from the unique resources of The RAND Corporation. The extent to which that promise is being fulfilled may be inferred from the recent accomplishments and ongoing activities of the Institute, which are described in Sections II through IX of this report.

Each of the following sections addresses one of NDRI's research programs. The sections begin with a discussion of the issues addressed by the program and of the program's research activities during contract year 1987. A list of publications and briefings is included. Each section concludes with one or more research highlights summarizing the findings of key research. (Some of NDRI's work is classified. This report does not contain classified material and does not list classified publications.)

II. International Economic Policy Program

Charles Wolf, Jr., Director

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The Program

As national economies have become more closely integrated in the world marketplace, questions of national security have become inextricably intertwined with those of international economics. For example, what are the security implications of increasing trade between the Western democracies and the Soviet Bloc? How do market reforms affect a centrally planned economy such as that of the Soviet Union? How acute is the competition for resources between civil and military sectors in the Soviet Union, and how is that competition resolved? What are the economic factors impinging on the defense programs of the United States and its allies and on their ability and willingness to bear the burdens of the alliance? How can economic theory illuminate and improve analysis of the burden-sharing problem? What are the costs and benefits of overseas bases to the United States and to the host countries?

Addressing these issues requires expertise in national security and economics as well as the ability to address their interactions. Government staff with responsibility and expertise in one or the other of these fields tend to be organizationally separated from each other. For example, analyses by the International Monetary Fund, the World Bank, and the European Economic Community typically omit issues of NATO defense expenditures and transfers or leakages of militarily useful technology. In the United States, economists at the Treasury Department and the Council of Economic Advisers generally do not deal with national security issues, while defense agencies have limited technical capabilities in international economics.

This organizationally stimulated neglect is exacerbated by differences in staff training. The contrasting sociologies, research paradigms, and intellectual histories of economists and military analysts predispose them to insularity, as well as to possible misunderstandings when they try to communicate across their disciplinary borders.

The FFRDC provides an ideal environment within which to break down disciplinary barriers and bridge issues that need to be linked for better defense policymaking. NDRI's economists have chosen this venue for their research so they can contribute to defense-

related issues; they can draw on the expertise of RAND's military analysts, who have over the years sought to interact with a variety of disciplines. NDRI's International Economic Policy Program was established to encourage interaction between economists and defense policy analysts by highlighting the international economic implications of national security issues and the national security implications of international economic issues.

ECONOMIES OF COMMUNIST COUNTRIES

One of the Program's principal goals has been to achieve a better understanding of the economies of the Soviet Union and other communist countries. Working under the sponsorship of the Director of Net Assessment (NA) and of the Under Secretary of Defense for Policy (USDP), NDRI researchers have attacked this problem from a variety of angles.

One approach was taken in an August 1987 RAND Report by C. R. Neu and John Lund, *Toward a Profile of Soviet Behavior in International Financial Markets*. Here, Dr. Neu not only described the general proclivities of Soviet financial agents but also set out the Soviet hard-currency balance sheet, building on previous Institute research to suggest the destination of "missing" lending. (See the research highlight following this narrative.)

Other researchers in the Program are examining the domestic side of the Soviet economy. Departing from traditional attempts to model the Soviet economy as a mirror image of Western industrial economies, Gregory Hildebrandt and his colleagues are devising new approaches that account for peculiarly Soviet characteristics, e.g., centrally established demand priorities and defense penetration into the civil sector. The Program will be expanding this line of research in 1988 through a conference on the defense sector in the Soviet economy, organized in collaboration with the Hoover Institution, and in a major project on the allocative choices facing the Soviet leadership. Meanwhile, Stephen Popper and Keith Crane are looking at an often-ignored source for inputs to Soviet growth and modernization—namely, the other European members of the Soviet Bloc. These countries are being obliged

to close their trade deficits with the USSR via better quality exports, and previous RAND research has identified over 1200 industrial specialization agreements intended to better integrate Soviet Bloc manufacturing and technology.

Program director Charles Wolf, Jr., and Benjamin Zycher are examining communist systems more generally, attempting to identify whether and to what extent the military dimensions of communist countries substantially differ from those of noncommunist nations and how this might be explained. Paul Henze is comparing economic performance and the burden of military expenditures in revolutionary Ethiopia with those of a geographically similar neighboring country, Kenya.

REGIONAL ISSUES

The Ethiopia project also exemplifies the Program's studies of regional issues. With one exception, these projects are sponsored by USDP. For example, Daniel Kohler has been analyzing the relationship between varying economic growth rates in sub-Saharan Africa and the role of military governments.

Other researchers have focused on China and the Philippines. For the Director of Net Assessment, K. C. Yeh is analyzing the economic and technical capabilities of the People's Republic of China to pursue alternative paths to military modernization through the 1990s—and how those capabilities might be affected by U.S. policies concerning trade and military cooperation. Project work during 1987 included the development of a small macroeconomic model to assess the economic impact of alternative levels of defense spending in China. This research draws on prior work by Dr. Yeh on China's national accounts and its record of economic development from 1952 to 1985.

Dr. Crane, Donald P. Henry, and Katharine Webb assessed the value of the U.S. bases in the Philippines in terms of the costs of replacing the military capabilities they support and in terms of their benefits and costs to the Philippines. This joint military-economic analysis supports base negotiations being held in 1988 with the Philippines and also provides a methodologi-

cal framework for assessing the value of military bases elsewhere. It has been widely briefed to U.S. military and foreign-policy audiences in Washington, the Pacific Command, and the Philippines.

A number of regional studies have been conducted within a single project as part of RAND's participation in the Future Security Environment Working Group of the national Commission on Integrated Long-Term Strategy. Dr. Wolf and other program personnel have developed consistent estimates of gross national products, military capital stocks, and military spending of 15 countries between 1950 and 2010. The first phase of the work was briefed at the Commission's Summer Study in San Diego and was reflected in *Discriminate Deterrence*, the Commission's report to the Secretary of Defense and the President's National Security Adviser.

OTHER RESEARCH TOPICS

Two publications marked the end of an extensive investigation into export subsidies. In *Honor Among Nations. Enforcing the "Gentlemen's Agreement" on Export Credits*, Dr. Kohler and Peter Reuter examined the successes and limitations of the informal agreement among the Western industrialized countries to restrain subsidies of their exports. In *The Financial Cost of Export Credit Guarantee Programs*, Dr. Henry showed that the reported profits of export credit agencies have often masked true losses and examined in particular the record of the U.S. Eximbank. (See the research highlight.)

Program staff have been addressing the economics of U.S. defense management in two studies for the Director of Program Analysis and Evaluation. At the end of the contract year, RAND published *The Choice of Discount Rate Applicable to Government Resource Use. Theory and Limitations*. In this volume, James P. Quirk and Katsuaki L. Terasawa suggest a more pragmatic approach than has usually been offered for setting the rate on which present-value comparisons of government investment projects are based. (See the research highlight.) Dr. Terasawa is collaborating with Stanley Besen on economic models of the weapon system acquisition process. Their purpose is to take account of recent developments in economic theory

regarding auctions, complex contracting, and principal-agent relationships to support policy recommendations intended to improve the acquisition process. (At the end of the 1987 contract year, NDRI's research on defense economics was moved to the new Acquisition and Support Policy Program.)

The International Economic Policy Program is also engaged in related activities which, though funded outside the NDRI framework, indirectly enhance work done under NDRI auspices. For example, the Program director is helping the Pew Charitable Trusts manage a national research and training program designed to better integrate economics and national security. Other members of the Program staff are undertaking research for Pew on alliance burden sharing, the role of the military in economic reform in Eastern Europe and China, and the effects of military spending on civil technology. This work is being performed in collaboration with scholars at Princeton University, the Massachusetts Institute of Technology, the University of Chicago, Columbia University, the University of Maryland, the Hoover Institution, the American Enterprise Institute, and the Hudson Institute.

UNCLASSIFIED PUBLICATIONS

R-3444-USDP, *Military Spending in Eastern Europe*, Keith Crane, May 1987.

R-3491-USDP, *The Financial Cost of Export Credit Guarantee Programs*, Donald P. Henry, June 1987.

R-3524-USDP, *Toward a Profile of Soviet Behavior in International Financial Markets*, C. R. Neu, John Lund, August 1987.

R-3464-PA&E, *The Choice of Discount Rate Applicable to Government Resource Use*, James P. Quirk, Katsuaki L. Terasawa, December 1987.

N-2536-USDP, *Honor Among Nations: Enforcing the "Gentlemen's Agreement" on Export Credits*, Daniel F. Kohler, Peter H. Reuter, December 1986.

N-2585-OSD/FF, *Polish Economic Policy and Western Economic Leverage*, Keith Crane, July 1987.

N-2657-USDP, *Defense and Development in Africa. Annotated Bibliography*, James Rosberg, Kwabena Gyimah-Brempong, and Francois Goreux, October 1987.

SELECTED BRIEFINGS

Donald Henry, Katharine Webb, Keith Crane, *Assessing the Value of Philippine Bases. An Interim Briefing*, to staff, U.S. Forces, Korea; U.S. 7th Air Force, Subic Bay Naval Base; Clark Air Base; U.S. Embassy, Manila; U.S. Forces, Japan; U.S. 5th Air Force; U.S. Naval Forces, Japan; U.S. 7th Fleet; U.S. Forces, Northern Marianas, U.S. Pacific Command, Plans and Policy Directorate; U.S. Pacific Fleet; and U.S. Army, Western Command.

Gregory G. Hildebrandt, *Alternative Views of the Soviet Economy, Phase I*, to Director, Net Assessment.

C. R. Neu, *Toward a Profile of Soviet Behavior in International Financial Markets*, to Deputy Under Secretary of Defense (Planning and Resources).

Charles Wolf, Jr., *Long-Term Economic and Military Trends, 1950-2010*, to Commission on Integrated Long-Term Strategy.

Benjamin Zycher, *Military Dimensions of Communist Systems*, to Director, Net Assessment.

Research Highlight

SOVIET BEHAVIOR IN INTERNATIONAL FINANCIAL MARKETS

If informed policy choices are to be made in the ongoing political and military competition with the Soviet Union, the Western alliance must be able to assess the state of the Soviet economy. Such an assessment requires, among other things, a clear view of Soviet holdings and transactions in hard-currency financial markets. Because the Soviet economy is centrally planned, Soviet financial behavior may also provide insights into the political goals and motivations of high-level Soviet policymakers.

Unfortunately, Western understanding of Soviet transactions in the international financial markets is far from comprehensive. Analysts must rely on imperfect information supplied by Western parties involved in transactions with the Soviets. To integrate some of this information and evaluate possibilities for collecting more, C. R. Neu and John Lund conducted a study for the Under Secretary of Defense for Policy.¹ The study included analysis of published data on Soviet hard-currency transactions in financial markets and some 20 interviews with government officials, bankers, and other observers of international financial markets in Washington, New York, and London.

THE OBSERVABLE SOVIET HARD-CURRENCY BALANCE SHEET

The Soviet Union enjoys a good "name" in international credit markets. Few countries are able to borrow from Western banks on more favorable terms, mainly because the Soviet Union pays its loans on time, but partly because the Soviets maintain large amounts of hard-currency funds on deposit in Western banks. Those deposits as of the end of 1986 were estimated at \$15 billion by the Bank for International Settlements (BIS). Apparently, the Soviets value these deposits as loan collateral, as a reserve against short-term fluctuations in their need for hard currency, and as a hedge against the possibility that Western governments will at some point restrict their access to hard currency

loans. Indeed, on a number of occasions, the Soviet Union seems to have borrowed hard-currency funds for no reason other than to add to its hard-currency deposits.

Turning to the other half of the balance sheet, gross Soviet debt at the end of 1986 was estimated to be about \$38 billion by the BIS and the Organization for Economic Cooperation and Development (OECD).² Several nations have larger gross debts, and the Soviets' net hard-currency debt of some \$24 billion dollars is exceeded by numerous countries. It is generally recognized, however, that the BIS-OECD estimates of Soviet debt are incomplete—but how incomplete?

THE POTENTIAL FOR UNOBSERVED BORROWING

It has been suggested that Soviet-controlled banks operating in the West may forward loans to the Soviet Union in such a way that they are not recorded by the BIS. That could be done by passing funds through banks that do not report to the BIS or through transactions between West and East German banks, which are also not reported to the BIS.

While this is a plausible scheme, most experts believe that hidden borrowing is minimal. The Soviet-controlled banks, which report total assets on the order of \$10 billion, are too small to accommodate significant hidden additions to Soviet debt. False reporting would likely be discovered, and the Soviets value these banks too highly to risk them for whatever might be gained by hiding a few transactions.

Thus, present figures are probably close to correct. However, the Soviets may soon be entering the Euronote market, where debt issues may not be captured by current reporting requirements.

¹R-3524-USDP, *Toward a Profile of Soviet Behavior in International Financial Markets*, August 1987.

²The BIS and the OECD reported that about 48 percent of the gross Soviet debt was held or guaranteed by Western governments as a result of export credits. (Such credits have not been granted to the Soviet Union by the United States' Export-Import Bank since 1977.)

WHERE THE BORROWED FUNDS GO

In simple terms, the Soviets can do three things with borrowed funds: they can allow reserves to accumulate, they can finance imports, or they can lend (or give away) the money. In 1983, for example, BIS and OECD figures indicated a \$1.4 billion excess of borrowing over lending by the Soviets. There was no appreciable growth of reserves. Thus, one would have expected that Soviet net imports of goods and services would have been \$1.4 billion. Instead, the Soviets experienced net exports of \$5.4 billion in 1983, according to the U.S. Central Intelligence Agency. If the accounts are to balance, we must assume that the Soviets undertook enough unobserved lending to balance the observed net borrowing plus the currency brought in by the net exports, or a total of \$6.8 billion.³ Where might this money have gone?

The most likely recipients of unobserved Soviet hard-currency lending are the USSR's Third-World "client" states outside the Soviet Bloc's Council for Mutual Economic Assistance (CMEA). (Hard-currency transactions are much less prevalent within the CMEA, whose Third-World members are Mongolia, Vietnam, and Cuba.) Indeed, other RAND research has indicated that Soviet loans and aid to non-CMEA countries amounted to \$6.9 billion in 1983.⁴

³More precisely, a capital-account surplus of \$1.4 billion and a current-account surplus of \$5.4 billion were observed, requiring an unobserved capital-account deficit of \$6.8 billion.

⁴R-3419-NA, *The Costs and Benefits of the Soviet Empire, 1981-1983*, Charles Wolf, Jr., et al., August 1986.

THE SOVIET STYLE OF OPERATIONS IN THE FINANCIAL MARKETS

In international credit markets, Soviet financial managers are perceived as very hard bargainers, seeking and often getting very good loan terms. They have shown a preference for repeated borrowing in moderate amounts, instead of arranging less frequent "jumbo" credits. They thus maintain a regular presence in the markets, drawing less attention to their borrowing than they might otherwise.

In money markets, the Soviet style is very conservative. Almost all Soviet hard-currency assets are in bank deposits with maturities of less than a year.

In foreign-exchange markets, Soviet financial managers are active and aggressive, sometimes transacting in very large lots. In doing so, they stake out a position for themselves as major players, reducing their dependence on other participants and thereby gaining some privacy.

DIRECTIONS FOR FUTURE RESEARCH

The NDRI analysis should be regarded as preliminary. Firmer conclusions will have to await further research. **Our knowledge is especially incomplete in regard to the channels and methods of Soviet transactions.** Much could be gained from a systematic review of the financial press and of information published by foreign banks and ministries, from further interviews with foreign bankers and financial-market observers, and from efforts to gain access to sensitive financial information.

Research Highlight

EXPORT SUBSIDIES: CONTROLS AND COSTS

The governments of the major industrialized nations all subsidize the purchase of some of their exports by foreign buyers. In such cases, the exporter's government may loan money to the foreign buyer at an interest rate below the government's own cost of borrowing; or, the government may loan money or guarantee loans made by others without collecting an insurance premium high enough to cover the risk of default.

The United States objects to export subsidies on two grounds. First, if all nations subsidizing exports did away with those subsidies, they would all be better off economically. Second, Eastern Bloc countries are among the major beneficiaries of export subsidies.

NDRI has been examining export credit subsidies under the sponsorship of the Under Secretary of Defense for Policy. The most recent analyses focus on two aspects of the problem: international measures taken to control export subsidies and the financial cost of those subsidies.

THE "GENTLEMEN'S AGREEMENT"

The Arrangement on Guidelines for Officially Supported Export Credits has been signed by 22 countries—including the major noncommunist European nations, the United States, Canada, Australia, New Zealand, and Japan. The arrangement, commonly referred to as the "gentlemen's agreement," is intended to restrict subsidies through the establishment of minimum allowable interest rates and maximum terms for export loans. The agreement is not enforced by any agency. A signatory may simply "derogate" from the agreement and offer a loan with a lower interest rate or a longer term than that allowed, but a derogation must be announced at least 10 days in advance. Any other participant may then also break from the specifications of the agreement and compete with the initial derogator on the nonconforming loan. The conclusions of the NDRI analysis¹ are as follows.

¹N-2536-USDP, *Honor Among Nations: Enforcing the "Gentlemen's Agreement" on Export Credits*, Daniel F. Kohler and Peter H. Reuter, December 1986.

The agreement does appear to have restrained competition in direct subsidies. According to organizations with an interest in policing conformity with the agreement, violations of the notification requirement are rare enough that records are not kept in that regard. Indeed, one might expect the agreement to be self-enforcing. If a derogator fails to give warning, it is in the importer's interest to do so.

Still, officials involved in operating the agreement report that participants are concerned about violations of the notification requirement. One strategy for reducing the number of derogations and violations would be to tax participants on their subsidies and use the proceeds to establish a fund for subsidizing those who wish to compete against derogators.

The gentlemen's agreement faces a major threat in the growth of subsidized exports by the newly industrialized countries, e.g., Brazil, South Korea, and Singapore, which can gain a greater share of the export market by undercutting the agreement's minimum rates. These nations may not find it in their interest to become participants in the agreement.

But the most important limitation of the gentlemen's agreement is that it applies only to direct credits. It does not apply to loan guarantees and insurance of risky loans. It is thus not surprising that these indirect subsidies are a growing fraction of the total volume of export credits and guarantees.

THE FINANCIAL COST OF EXPORT SUBSIDIES

Subsidies cover over 10 percent of the total dollar volume of exports for the United States, the United Kingdom, West Germany, and France. It is claimed, however, that export subsidies do not cost the governments anything. Indeed, export credit agencies often report profits. Yet a subsidy implies anticipation of loss on money paid out. Can this be compatible with reported profits?

NDRI examined those programs in which governments subsidize exports by assuming risk—either in guaran-

teeing or recovering on a loan.² It was found that the agencies actually do operate at a loss. In the first three years of this decade, those losses amounted to a combined total of \$3 billion in the four countries mentioned above (see the table).

**FINANCIAL BURDEN
OF RISKY EXPORT SUBSIDIES**
(Millions of dollars)

Year	U.S. (Eximbank)	U.K. (ECGD)	W.Germany (Hermes)	France (COFACE)
1979	\$84.4	\$195.5	\$10.8	\$421.1
1980	507.0	214.9	84.1	357.9
1981	172.7	122.9	88.3	282.1
1982	127.1	316.1	111.6	592.0
1983	270.1	381.4	253.9	—
1984	761.9	—	—	—

Why does the actual record of the export credit agencies differ so much from the data they report? The answer lies in two peculiarities of the agencies' accounting methods:

- The agencies generally track cash flows instead of accounting by accrual. Thus, losses from past loans are offset by income from current ones, and, as in a Ponzi scheme, a positive cash flow is recorded as long as the volume of loans is growing. The RAND analysis balanced the risk premiums paid when loans were made against payments on those loans expected in the current year but not received.

²R-3491-USDP, *The Financial Cost of Export Credit Guarantee Programs*, Donald Putnam Henry, June 1987.

- The agencies are reluctant to write off loans. It is assumed that sovereign borrowers will ultimately repay their loans in full. In the United States, the Export-Import Bank still carries prerevolutionary Cuban and Chinese loans on its books at full face value. In the analysis reported here, losses were charged on the basis of the historical record.

The inappropriate accounting methods employed by the export credit agencies have implications for their stated net worth. The Eximbank, for instance, claims a net worth of \$1 billion—the capital stock initially provided by the Treasury in 1937. However, generally accepted accounting principles would not allow the Bank to accrue interest on nonperforming loans, as it does, and would require that it set aside reserves based on expected losses, which it does not.

Also, because the Eximbank borrows money to cover its loans at higher rates than it loans money out, it has committed itself to losses for years to come. Its "book value" thus overstates its market value. Furthermore, the initial \$1 billion could have shown a profit had it been invested otherwise. Thus, instead of protecting the initial investment as claimed, the Eximbank has actually resulted in a total opportunity cost to the U.S. public of 3.2 to 4.0 billion dollars.

The NDRI analysis did not attempt to measure any benefits that might be realized from officially supported export credits. Also, the form in which the export credit agencies publish their data is not the most suitable for analysis, so the results are imprecise. Indeed, it is partly because of such imprecision that the agencies refuse to estimate true losses. However, the losses reported here are undoubtedly closer to the truth than the no-loss assumption of the agencies. NDRI's cost estimates should thus provide governments with a more accurate basis for deciding about the continuance of export subsidies.

Research Highlight

SETTING THE DISCOUNT RATE FOR GOVERNMENT PROJECTS

For most government investment projects, a benefit-cost study is conducted to determine whether the benefits generated (expressed in dollar terms) will exceed the costs of the project. Because both benefits and costs are normally spread out over a number of years, the question arises as to how to compare future dollars (adjusted for inflation) with present dollars. Future inflation-adjusted dollars are discounted, i.e., they are treated as worth less than present dollars, for two reasons. First, a present dollar can be invested to return more than a dollar in the future, and, second, consumers are "impatient" and prefer consuming a dollar's worth of goods today to consuming a dollar's worth of goods in the future.

In government benefit-cost studies, the inflation-adjusted discount rate used for calculating the present value of a future dollar is 10 percent per annum, as set by the Office of Management and Budget in 1972. Over the past 35 years, the inflation-adjusted interest rate earned by Treasury bills has averaged out to a little less than 1 percent per year. That might lead one to wonder whether the official 10 percent discount rate shouldn't be lower. Indeed, a number of economists have addressed that issue. We report here on a study sponsored by the DoD's Director of Program Analysis and Evaluation, in which two NDRI researchers—James Quirk and Katsuki Terasawa—reviewed and extended economic theory relating to the choice of a government discount rate.¹

Briefly, the current state of economic theory regarding choice of a government discount rate can be summarized as follows.

1. In a perfectly competitive world free of externalities and other distortions such as those induced by government taxes and regulations, the correct government discount rate would be the market rate of interest faced by consumers and firms. The government would invest

only in those projects (but in all those projects) having a discounted net present value greater than zero, i.e., projects whose discounted benefits exceeded discounted costs. The market rate of interest would be the "correct" rate in the sense that it would lead to an efficient allocation of resources for society over time. That is, it would lead to an allocation yielding as high a rate of return as would any other.

2. Now, imagine a "second best" world in which the only distortion is the corporate income tax. Here, the correct government discount rate would be a weighted average of the pretax corporate rate of return and society's *social rate of time preference*. The latter is the rate at which society discounts the satisfactions of future years (and thus future generations) relative to the present. Under highly special conditions, the social rate of time preference can be shown to be equal to the rate of interest that consumers face. As those conditions seldom prevail, it is generally not practical to derive the "correct" government discount rate with this method. In theory, however, the government would again use the discount rate to determine whether the discounted present value of each project is positive, that being the sole basis for determining whether to invest.

In the NDRI study, the choice of a government discount rate is examined under what may be a more realistic set of conditions than those of a distortion-free or second-best world. The argument runs as follows. In the real world, the level of government investment spending—and thus the number of projects funded—is not determined by the choice of the government discount rate. Instead, it is set on the basis of a complex set of factors, including macroeconomic stabilization and political considerations. In practice, passing the benefit-cost test for positive present value is only a prerequisite for funding; it does not guarantee funding. Thus, the benefit-cost test only acts to identify a set of projects with varying levels of net benefits. Congress can use noneconomic reasons to fund relatively low-payoff projects when projects offering higher returns are available but unfunded. Hence, attempting to choose a government discount rate via the "second best" approach leaves the door open for an inefficient portfolio of government projects.

¹IR-3464-PAE, *The Choice of Discount Rate Applicable to Government Resource Use. Theory and Limitations*, December 1987.

The benefit-cost threshold should thus be raised so that the projects that pass the test would not require a total investment greater than the funds available. The government would continue to fund all projects with positive net benefits, but now only those projects with the highest rates of return would have positive net benefits. Thus, only the most economically efficient portfolio of projects would be eligible for funding. **The discount rate responsible for the higher benefit-cost threshold is the opportunity cost rate of return, i.e., the highest rate of return available from the set of unfunded projects.²**

Of course, the opportunity cost rate of return varies with the level of government investment spending. The more the total investment, the lower the opportunity cost rate of return, and conversely.

It is widely recognized by economists that the uncertainties involved in predicting benefits and costs allow plenty of room for manipulating the figures so that net benefits turn out to be positive. Thus, biased benefit-cost estimates can swell the pool of projects eligible for funding, but not if the opportunity cost rate of return is used. In the latter case, no more projects would be available for investment than could be funded with

²This rate, which is dependent on the threshold it defines, can be set iteratively. A likely rate might be chosen, present values calculated, and the total investment for positive-value projects determined and compared with the funds available. Then the rate would be adjusted and the process repeated until the total investment and the funds available equate.

unbiased estimates. Inflated estimates would only lead to an inflated discount rate. No one would know how much an estimate had to be fudged to get a project to pass the benefit-cost test. Still, if manipulation continues and projects are overestimated by varying proportions, the set of projects chosen under the new approach—or any other—would probably not be the “correct” one. Thus, regardless of the method chosen to set the discount rate, **establishing independent review of cost-benefit estimates would mitigate potential bias problems.**

The new approach is based solely on economic efficiency and does not take into account any inequities in the distribution of benefits and costs between generations. Under the “second best” approach, the discount rate could be set somewhat lower than the “correct” level so as to discount future net benefits less and avoid the temptation to deprive the next generation. But if, as assumed under that approach, all projects with positive net benefits were funded, lowering the discount rate would lead to the approval of more projects, shifting investment resources from the private sector to the public sector. Under either approach, **it would be preferable to solve possible intergenerational inequities through monetary and fiscal policies** intended to lower the market rate of interest and induce investment in private-sector projects with greater benefits in the future.

Drs. Quirk and Terasawa have briefed officials at PA&E, OMB, and the Council of Economic Advisers on the new approach. PA&E is drawing on the NDRI analysis in developing proposals for its ongoing discussions with OMB regarding the federal discount rate.

III. International Security and Defense Policy Program

Michael D. Rich, Director (acting)

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The Program

The International Security and Defense Policy Program examines political-military problems at the national level, without limitation by the concerns of the individual military services. Guided by this orientation, the Program's research revolves about several unifying themes. The most important is the changing nature and implications of the external challenges facing American defense planners.

LONG-TERM COMPETITION WITH THE SOVIET UNION

Foremost among the challenges facing defense planners is the long-term competition with the Soviet Union. Here, the Program's research in recent years has considered such questions as the following:

- Evolving Soviet military doctrine and policy.
- Trends in Soviet domestic policies as they bear on American security.
- Soviet R&D and the USSR's economic base as they affect Soviet military prowess.
- The cohesion, reliability, and combat strength of the Warsaw Pact.
- Changing patterns of Soviet political and military involvement in world affairs.

To cite a specific example from contract year 1987, Research Support was used to fund an analysis of recent Soviet writings on potential organizational and operational shortfalls in the Soviet homeland mobilization system.

The Program also strives to foster better understanding of the policy options that might accommodate the Soviet challenge, including arms control and its strategic consequences. Several recent and ongoing projects within the International Security and Defense Policy Program entail political or historical analyses of arms control initiatives. Military and technical assessments of arms control questions are generally undertaken in other programs.

At its 1986 meeting in Halifax, NATO launched an effort to develop new initiatives for conventional arms control in Europe. At NDRI, Richard E. Darilek leads

a newly started project intended to help identify and analyze such initiatives, particularly those aimed at curbing the use (vs. reducing the numbers) of conventional military forces. This work builds upon related studies in all three of RAND's national security FFRDCs.

William R. Harris has recently begun development of a microcomputer-based system for organizing and displaying data on the record of arms control treaty performance. He will be updating the quantitative indicators of Soviet compliance and noncompliance that he developed earlier in the contract year. The objective is to facilitate development of performance-based arms control strategies, negotiation of arms control agreements, formulation of responses to noncomplying behavior, and linkage of arms control policies with other national security objectives. The prototype system will be reviewed with staff of the Office of the Under Secretary of Defense for Policy to assure that the system has continuing pertinence for arms control decisionmaking. In other compliance work outside the sphere of arms control, Research Support funds were used to respond quickly to a request from the USDP for information regarding communist violations of prior peace accords in Korea and Indochina.

POLITICS AND SECURITY IN EUROPE

A second set of external challenges facing U.S. defense planners are those relating to the politics and strategic implications of NATO defense planning. In the Program's principal ongoing study of European security in the political context, Associate Program Director James Winnefeld is evaluating the likely performance of the NATO political and military command structure during the transition from peace through crisis to war. Six scenarios, including some not normally planned for, have been developed to illustrate the possible performance of current arrangements. The study has been particularly concerned with the wartime functions of NATO's Defense Planning Committee, NATO's planning assumptions of adequate warning and uninterrupted mobilization, and planning for deescalation in the event of successful deterrence at the brink of war. A second project reviewed current and prospective U.S. basing arrangements on NATO's southern flank.

POLITICS AND SECURITY IN THE THIRD WORLD

Yet another set of challenges arises from the various regional security relationships around the globe, particularly in the Pacific Basin, the Middle East, Latin America, and Southwest Asia. NDRI researchers are seeking to clarify the implications that Third World security relationships might have for our allies and potential adversaries.

Three of NDRI's recent projects on regional security issues have focused on **Central America**. David W. Ronfeldt and his colleagues interviewed members of the Honduran political and military elite to determine how they perceived U.S. involvement in Central America and how their perceptions might affect security cooperation with the United States. With funds from Research Support, Dr. Ronfeldt organized a conference on the Nicaraguan resistance that included presentations by the former U.S. defense attaché in Nicaragua and a former associate of the United Nicaraguan Opposition. The conference was cosponsored with three other RAND components—the Arroyo Center, Project AIR FORCE, and the Political Science Department. In the third study on Central America, RAND analysts projected trends in the Nicaraguan security threat in the event of failure of the resistance to overthrow the Sandinista regime (see the research highlight).

George K. Tanham has analyzed the connections that the Soviet Union and other anti-Western countries are trying to form with the **Pacific island states** of Fiji and Vanuatu. Of all the South Pacific nations, the latter are of special importance because of their peculiar vulnerabilities to Soviet penetration and destabilization. Dr. Tanham also identified U.S. options for countering Soviet initiatives in the region. Research Support was used to fund another Pacific basin study; this one developed a framework for comparing the results of various evaluations of a country's stability, with evaluations of the Philippines serving as an example.

Three studies of **mainland Asian countries** have been undertaken. Jonathan D. Pollack is assessing China's capabilities for integrating U.S. military technology within its defense establishment. The assessment includes an exploration of China's defense

acquisition procedures, an evaluation of how China plans and manages defense R&D, and a projection of the effects of U.S. assistance on the future of the U.S.-China security relationship. Nikola B. Schahgaldian is examining the prospects for the durability of the ruling clerical establishment in Iran. Interviews are being conducted with a number of former Iranian government officials and clerics, along with foreign observers, to gain a better understanding of internal Iranian political power centers and the possibility for instability after Khomeyni's death. The third Asia study drew operational lessons the Soviet military may have learned from the war in Afghanistan.

Gordon McCormick and Edward Gonzalez are looking at the Soviet system of client control **throughout the Third World**. They are integrating information on Soviet bloc military and economic assistance to Third World clients, bloc advisory personnel in Third World nations, interclient personnel exchanges, and Soviet-client treaty networks. Interviews will be carried out with client-state emigrés and defectors. With the information, the investigators hope to offer insights into the structure of the client system, patterns and methods of control, problems of friction and discipline, internal and external vulnerabilities, and how the latter might be exploited. This research is an extension of a large body of RAND work over the past three to four years on Soviet Third World policy.

Two other projects have addressed diverse third areas. One reports on the nature, scope, and goals of insurgencies against Soviet client regimes in Angola, Ethiopia, and Afghanistan, along with their potential for impeding or reversing Soviet influence gains in those areas. The other, cosponsored by the Director of Program Analysis and Evaluation, compares the effectiveness of different means of delivering firepower to Third World allies in various contingencies.

THE DOD POLICYMAKING PROCESS

Another category of the Program's work entails periodic research conducted either at RAND's or a client's initiative on topics relating to the process by which our sponsors in OSD and the OJCS make defense policy. These responsibilities embrace, among other things, preparing the annual defense guidance,

participating in the arms control process, countering espionage; and managing alliance relationships.

NDRI research in this area is directed to issues of counterintelligence and related efforts to maintain the security of classified information. Dr. Darilek is leading a project to examine the effectiveness of controls on dissemination of sensitive defense information. Project staff members are evaluating whether sensitive information on selected topics might be available to hostile intelligence forces through open sources and how such information might be identified, collected, and analyzed by those forces. The intent is to identify any deficient aspects of current controls and to help policymakers decide whether more or less classification is required.

The Defense Personnel Security Research and Education Center, established in 1986, has developed research agendas intended to contribute to improved personnel security policies. Carl H. Builder has been directing an NDRI evaluation of those agendas, including the formulation of alternative agendas. Emphasis is being placed on the need for work on theoretical underpinnings and the development of policy alternatives significantly different from those in place.

Some of NDRI's 1987 research supported DoD policymaking related to issues of domestic security. For instance, the military role in interdicting the flow of illegal narcotics into the United States is increasing. NDRI recently issued a report concluding that large increases in interdiction success would have only a modest effect on drug smuggling and that military involvement would not necessarily result in much more successful interdiction (see the research highlight).

CONCLUSION

NDRI anticipates that the International Security and Defense Policy Program will continue to address the political and strategic ramifications of a broad range of security issues—globally, regionally, and domestically.

However, some evolution of emphasis is likely. NDRI has been making a concerted effort to expand its research on Soviet domestic issues in the hope of gaining some insight, for instance, into the implications that ongoing economic and institutional reforms might have for Soviet military activities. The Institute's agenda will complement research on Soviet issues carried out in RAND's other FFRDCs. It will draw on the expertise of members of the RAND-UCLA Center for the Study of Soviet International Behavior (CSSIB), housed outside NDRI within RAND's National Security Research Division.

UNCLASSIFIED PUBLICATIONS

R-3431-USDP, *Building Confidence and Security in Europe: The Potential Role of Confidence- and Security-Building Measures*, Y. Ben-Horin, R. E. Darilek, M. Jas, M. F. Lawrence, and A. A. Platt, December 1986.

R-3473-USDP, *The Iranian Military under the Islamic Republic*, Nikola B. Schahgaldian and G. Barkhordarian, March 1987. (A summary has been issued as RB-7401, September 1987.)

N-2588-OSD, *Country Assessments and the Philippines*, Jeffrey Simon, March 1987.

SELECTED BRIEFINGS

Carl H. Builder, *Rationalizing the Personnel Security Research Agendas. A Progress Report*, to Deputy Under Secretary of Defense for Policy, Assistant Deputy Under Secretary of Defense (Counterintelligence & Security).

David C. McGarvey, *Comparing Ways to Deliver Firepower to Third Areas*, to Staff, Program Analysis and Evaluation.

Jonathan D. Pollack, *Chinese Acquisition of U.S. Defense Technology. Project Status*, to Staff, East Asia-Pacific Division, OASD (International Security Affairs).

Research Highlight

DRUG INTERDICTION AND THE MILITARY

As concern about illicit drug use in America has grown over the past decade, greater emphasis has been placed on capturing drug smugglers and seizing their shipments. Yet such interdiction activities have had limited effect on drug availability and consumption. Cocaine, for instance, enters the United States in increasing quantities and at ever lower prices.

Many people believe that drug interdiction would be more effective if the relatively minor role played by the military were expanded. To assess the potential gains from greater military involvement, an NDRI research team led by Peter Reuter collected information from the literature and relevant agencies, and organized a conference on the topic. The analysts constructed and ran models of the behavior of smugglers responding to expanded interdiction and analyzed pertinent military assets.¹ The central question was broken into two parts:

1. What gains might be realized by increased interdiction activities?
2. Could the military contribute significantly to an expanded interdiction effort?

The study, sponsored by the Under Secretary of Defense for Policy, concentrated on cocaine and marijuana smuggling. Interdiction of the third major imported drug, heroin, was not judged amenable to military assistance.

THE EFFECTS OF INCREASED INTERDICTION

How should the effects of interdiction be measured? The goal of interdiction is to decrease U.S. drug consumption, but consumption is not readily measured. The usual criterion of success—quantity of drugs seized—is affected by factors external to the interdiction effort. For instance, the quantity of marijuana seized has declined by about 50 percent in the last five

years, while that for cocaine has risen tenfold. But the decline in marijuana seizures could be due to a shift of production to Mexico (from where the drug is shipped over less vulnerable land routes) and to the United States itself. The increase in cocaine interdicted is likely due to an increase in the quantity shipped and a decrease in the drug's price on export (which makes loss of a shipment less important to the smuggler).

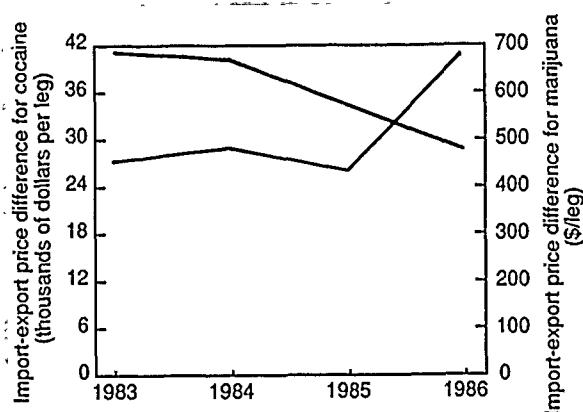


Figure 5
Trends in Import-export price differences

The RAND team recommended a measure more directly related to consumption. Interdiction would appear to affect consumption by raising the price of the drugs on import, and thus eventually the retail price. It does this not so much by removing drugs from the market (the source is not readily exhaustible), but by raising the risks and costs of smuggling. As risks are raised, so are the prices demanded of importers. **The most direct measure of interdiction effectiveness is thus the import price charged by the smugglers minus the export price they paid.** That price difference has increased in recent years for marijuana and decreased for cocaine (see Fig. 5). Thus, by this measure, the relative success of interdiction efforts against marijuana compared to those against cocaine is the opposite of that indicated by the seizure record.

To gain some quantitative understanding of the effects of interdiction, the researchers modeled the smuggling-

¹R-3594-USDP, *Sealing the Borders: The Effects of Increased Military Participation in Drug Interdiction*, Peter Reuter, Gordon Crawford, and Jonathan Cave, January 1988.

interdiction relationship. The RAND model differs from models devised in prior studies in that it simulates adaptation (i.e., alternative route selection) by smugglers in response to route-specific increases in interdiction. The model calculates export price, import price, retail price, and U.S. consumption on the basis of a variety of inputs, including initial export price, shipment sizes and rates, risk compensation required, probability of interdiction, and smuggler's cost if interdicted.

Route-specific estimates of smuggling and interdiction were made for a network of 10 air and sea routes with currently typical interdiction probabilities of 20 to 25 percent and one land route with an interdiction probability of 10 percent. Air and sea interdiction rates were then raised to 50 percent on an increasing number of routes. As shown in Fig. 6, the effects on cocaine smuggling and consumption were not very substantial unless interdiction probabilities could be doubled on more than half the routes. The results for marijuana seemed more promising (Fig. 7). However, the model does not take into account any offsetting increases in domestic production. Also, during the simulations, interdiction resources were randomly switched from route to route between shipments in an effort to limit smugglers' adaptive responses. That might prove difficult to accomplish in the real world.

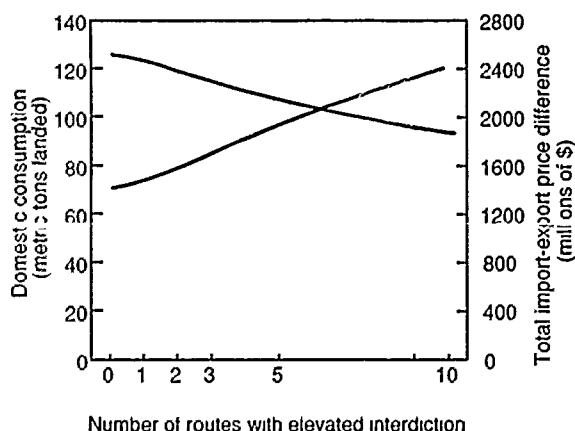


Figure 6

Increasing cocaine interdiction has limited effects on consumption and smuggling

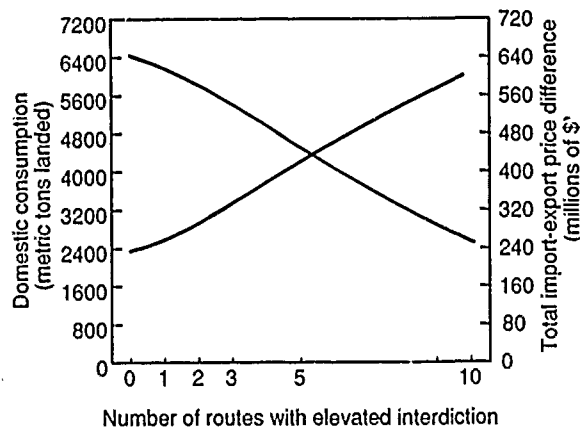


Figure 7

Substantial increase in marijuana interdiction has considerable effect on consumption and smuggling

The model's results have to be regarded as suggestive, as a number of simplifying assumptions were required in the calculations. But the overall effect of those assumptions was probably to inflate the likelihood and effects of interdiction. It thus seems improbable that a more precise model would yield more encouraging results.

THE POTENTIAL FOR MILITARY CONTRIBUTIONS TO INTERDICTION

Should the results of increased interdiction be judged worth the effort, what role could the military play? **Military interdiction assets would be of most use against smuggling by air, especially in surveillance of air routes.** Airborne radars mounted on the Navy E-2 and the Air Force E-3 aircraft are already employed in surveillance of smuggling routes. Currently, however, such surveillance is undertaken only in conjunction with military training missions. The E-3, or Airborne Warning and Control System (AWACS), has not been of much help because its training missions are scheduled weeks in advance and are oriented toward finding aircraft faster and larger than most drug-smuggling planes.

An expanded military role might include making the E-2 and E-3 more responsively available. These air

craft could mount an intensive air surveillance effort anywhere along the southern border of the United States with little preparation and with fairly low likelihood that smugglers would be aware of their presence.

Unfortunately, both the E-2 and E-3 are almost always in demand somewhere in the world to ensure the readiness of U.S. or allied forces, and their importance in wartime demands a cadre of well-trained operators. Balancing those needs with the need to combat air smuggling would be difficult.

Three tethered aerostats, or stationary balloon-mounted radars, are in operation around the perimeter of Florida. Congress has funded six additional aerostats for the Air Force, all to be devoted to drug law enforcement. Five of the new aerostats will be installed along the Mexican border. Their performance in this more rugged terrain is conjectural.

In any event, **enhancing surveillance still leaves the task of identification up to the interdiction agencies.** The military is not likely to be much help at picking probable smugglers out of the plethora of radar-located aircraft.

At present, the Customs Air Branch appears to have enough suitable aircraft to follow those planes identified from surveillance as possible drug carriers. Military pursuit aircraft are not designed for drug interdiction. Jet fighters would close on the typical smuggler's plane so fast that it would be difficult to trail the target discreetly. Even so, the fighter would be operating so close to the lower end of its velocity range that it might run out of fuel before it could return from the chase.

Personnel aboard the pursuit aircraft cannot count on making an arrest themselves, as the smuggler can block his landing strip once he is down. If the military is to have a role in arrest, helicopters would be required to transport arresting troops to the landing strip. The Army's Blackhawk, which can carry 11 troops and fly

at 160 knots, could be deployed in small numbers at military bases along the southern border of the United States.

The effectiveness of marine interdiction is not likely to be increased significantly through participation of Navy marine assets. Again, the trick is to pick out the smugglers. A battleship will not do much better than a 100-foot cutter in finding and pursuing drug-smuggling vessels. The Navy, because of its global deployment pattern, does not maintain a large number of ships in the Caribbean or along other parts of the major drug importation routes.

Increased military involvement is not likely to aid in curtailing smuggling over land routes. Individuals can carry high-value quantities of cocaine on their person, and the difficulty of intercepting people walking across the border is demonstrated by the influx of illegal immigrants from Mexico.

CONCLUSIONS

The questions addressed by the NDRI study might thus be answered as follows:

1. Increased interdiction is not likely to substantially reduce cocaine availability in the United States. The effects on marijuana consumption are less clear.
2. The military would probably not be able to contribute significantly to interdiction at sea or on land. Military assets could be of significant assistance in surveillance of air routes, but those assets are also required for the defense of the United States and its allies.

The NDRI analysts did not, however, attempt to compare the value the nation might place on small reductions in domestic drug consumption with the decrement in defense capabilities required to achieve that reduction.

Research Highlight

THE NICARAGUAN SECURITY THREAT IN THE 1990s

The threat Nicaragua may pose to U.S. security interests in the future is one of the most important uncertainties for U.S. defense planning in the Caribbean Basin. To clarify the likely evolution of the Sandinista threat in the 1990s, a team of RAND analysts reviewed the goals and actions of the Sandinistas in light of the patterns of relationships that often develop between the USSR and its Third World clients. The team's work was sponsored by the Director of Program Analysis and Evaluation.¹

The study reflected a concern that Nicaragua is well on its way to becoming a Soviet client regime. Since the Sandinistas came to power in 1979, Nicaraguan relations with the Soviet bloc and Cuba have been steadily solidified through increasing national-level contacts and subnational links. Between 2500 and 3000 foreign advisers and support personnel are attached to the Sandinista People's Army, and the Soviets provide close to a billion dollars a year in economic and military assistance to Nicaragua.

In evaluating the future threat, the analysts assumed that the Sandinistas would complete the process of political consolidation relatively unhindered by the Contra resistance, a meaningful peace treaty, or any U.S. policy initiatives, and that Central America would remain insecure. Other scenarios are possible, but the one employed here is in keeping with the patterns of recent years and represents an unfavorable case (but a reasonable one) that should be useful in planning U.S. policy. The team examined likely Nicaraguan behavior in four respects:

1. The development of Nicaragua's conventional military establishment.
2. Support for revolutionary insurgency in the region.
3. Support for international terrorism.
4. The potential for Soviet access to Nicaraguan military facilities.

¹R-3532-PA&E, *Nicaraguan Security Policy: Trends and Projections*, Gordon McCormick, Edward Gonzalez, Brian Jenkins, and David Ronfeldt, January 1988.

THE DEVELOPMENT OF THE SANDINISTA ARMED FORCES

The RAND analysts concluded that the buildup of a conventional fighting force in Nicaragua is probably being limited by the Army's speed in absorbing new arms shipments and the need to create special units to counter a guerrilla opponent (the Contras). If these constraints diminish, the Sandinista Army could increase further in numbers and reorient itself towards a more conventional force structure, improving qualitatively through force modernization, increased training, and improved quality of leadership. Over the next decade, it is anticipated that Nicaragua will attempt to acquire high-performance aircraft and that the Army's firepower and mobility will increase. Because the military balance in Central America is fragile, **continued development of the Sandinista People's Army would pose a mounting threat to regional stability** and could serve as a major instrument of political intimidation toward neighboring countries.

SUPPORT FOR REGIONAL INSURGENCIES

Serious though it may be, **the regional security threat posed by the Sandinista Army may prove less significant than the more subtle threat of Sandinista-promoted revolutionary unrest.** In coordination with Cuba and the Soviet Union, the Sandinistas have provided various kinds of support for a range of guerrilla movements and insurgents in El Salvador, Honduras, and Guatemala. Clearly, the Sandinista leadership remains committed to a "revolution beyond [its] borders."

Over the next decade, Nicaraguan assistance to insurgent movements throughout Central America is likely to continue. Indeed, Nicaragua's geographical location could make the country a focal point of armed revolt in Central America. In addition to its own support of revolutionary movements, the regime is likely to continue to allow Nicaraguan territory to be used by Cuba for the same purpose. However, the Sandinistas will probably proceed cautiously to avoid reprisals from the United States.

SUPPORT FOR INTERNATIONAL TERRORISM

It is possible that greater international isolation of the Sandinista regime or increased pressure from the Contras could motivate the Sandinistas to support terrorist activities. However, the RAND analysts could not find evidence suggesting likely Sandinista support for terrorism under the scenario assumed in this study.

Indeed, it was easier to find probable constraints on such support, e.g., the Sandinistas' concern about their international image, their desire for European aid, and the counsel of the Soviets and Cubans.

THE POTENTIAL FOR SOVIET ACCESS

The Soviets' significant military investment in Nicaragua presages an expanded future presence, probably including use of Nicaraguan military facilities sometime in the 1990s. Such facilities would augment their military presence in the Caribbean Basin and could allow, for the first time, a permanent Soviet air and naval presence in the eastern Pacific. With access to Nicaraguan airbases, the Soviets could be expected to commence reconnaissance flights along the Pacific coast of the United States, a practice that overflight and range restrictions have so far prevented them from undertaking. Nicaragua's Punta Huete airbase (see Fig. 8) will include a runway long enough to land any Soviet aircraft. Naval access is now limited by harbor depth and inadequate support facilities, but ongoing construction at Corinto, El Bluff, and Puerto Cabezas could change that within three to five years. For the immediate future, anticipated reactions by the United States are likely to condition Soviet activity, but as U.S. policy toward Nicaragua stabilizes, Soviet behavior will probably become less responsive to U.S. sensitivities.

EXTERNAL CONSTRAINTS

Assuming the availability of Soviet and Cuban support, the principal constraint facing Managua over the com-

ing years will be the direction taken by U.S. policy. If the U.S.-assisted Contra resistance keeps the Sandinista regime on the defensive—and particularly if Soviet support wavers—Nicaragua may not be able to fulfill its revolutionary role in the region. If, instead, the assumptions underlying this study prevail, the Sandinista regime will be relatively free to pursue its current direction.

Another possible source of constraint on the Sandinistas is a regional peace treaty. The NDRI analysis found that a Contadora-type treaty—one that sought to affect military behavior but not internal politics—might help to impose some limits on the projections stated above, but would not effectively constrain the overall Nicaraguan security threat. The treaty process now under way in Central America seeks to guarantee democratic change in addition to limiting military expansion and assistance. Whether that process will effectively constrain the threat is still open to question.



Figure 8
Major Nicaraguan military facilities

IV. Strategy Planning and Assessment Program

Paul K. Davis, Director

The Program

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The Program

Strategy operates in a complex, competitive environment. No one party makes all the rules or calls all the shots. The test of U.S. strategy is how well it supports the nation's policies and achieves U.S. objectives in the context of cooperative, competitive, or combative interactions with the strategies of other nations. The strategies that other nations will adopt and the forces they will employ to carry them out cannot generally be known with certainty ahead of time. NDRI's Strategy Planning and Assessment Program, and the RAND Strategy Assessment Center contained within it, assesses U.S. and allied strategies in this highly interactive and dynamic context, for both the near and more-distant periods.

Most of the topics taken up by the Program cut across disciplines and defense agency jurisdictions. The Program's work includes military and military-political assessments on both the theater and global level. It addresses issues of strategy, total-force structures, balances, and arms control, and develops innovative methodologies to assist in both long-term strategic planning and current-era operational planning.

METHODOLOGICAL WORK

The centerpiece of the Program's methodological work is the RAND Strategy Assessment System (RSAS), a newly developed and still evolving complex of integrated models and analyst aids that together constitute a system for *multiscenario analytic war gaming*. This system and the concepts for analysis that go with it were developed in the RAND Strategy Assessment Center (RSAC). The Center's facilities for gaming and analysis include 30 Sun workstations in RAND's Santa Monica and Washington offices. Program Director Paul Davis heads the Center and has directed the RSAS architecture development. Bruce W. Bennett and William Schwabe are the Program's (and Center's) associate directors.

The RSAS can represent strategies for and simulate events in conflict scenarios from military crisis through limited or general conventional or nuclear war, including any combination of escalation and deescalation within that spectrum. The capability to assess conven-

tional and nuclear issues on a theater-specific or global basis is a unique and powerful one for integrative national-level analysis. The RSAS is also a valuable analytical resource for more narrowly defined concerns, e.g., examining alternatives for conventional arms control affecting Europe's Central Region. The combat models used in the various conflict scenarios were developed under Dr. Bennett's direction. RSAS combat modeling is described further in the research highlight following this narrative.

Another unique aspect of the RSAS is that it includes optional decision models that can represent alternative forms of behavior at the political (national command) or military levels. The political behavior models, which have been developed under the leadership of Dr. Davis, afford helpful insights into matters such as deterrence, escalation control, and war termination. The military behavior models, which have been developed under the leadership of Dr. Schwabe, help gamers and analysts formulate *adaptive* strategies after having experimented with alternative concepts of operation in the light of possible opponent behaviors and other uncertainties.

The system's utility for national-level analysis and adaptive strategy formulation results from several characteristics of the system and its interface with the user:

- An emphasis on facing up to the challenge of planning under uncertainties in multiple dimensions such as political-military scenario, force capabilities, strategies, command-control, and even the "laws of war" used in models. This emphasis on confronting uncertainty is so foreign to defense analysis as to constitute a change in analytic paradigm.
- The complementary use of model-supported human war gaming, interactive simulation, and automated war gaming (closed simulations). Typically, RSAS studies begin with extensive gaming and interactive simulation. Experienced military specialists review and adjust model behaviors until a level of understanding has been reached that justifies more deductive analysis with closed simulations comparing alternatives and exploring sensitivities.

- Close man-machine cooperation, allowing analysts to directly use, review, and *interactively change* model behaviors. This is the result of a high degree of model transparency and flexibility in a general computer environment conducive to interactive work. The RSAS is written in a new computer language (RAND-ABEL™) that is remarkably understandable to analysts, and the RSAS environment includes many graphical displays, interactive user interfaces, and multiple windows. H. Edward Hall has been the principal figure behind development of this software environment.

By year's end, the RSAS was being used in a number of RAND studies sponsored by the Air Force, Army, OSD, and OJCS. It had also been installed in several government offices, and arrangements were being made to install it in about a dozen agencies or offices altogether. This is a major effort in itself, as the process of technology transfer is often difficult. However, the RSAS installations appeared to be progressing successfully.

STUDIES BY THE RAND STRATEGY ASSESSMENT CENTER

In contract year 1987, the RSAS was used to support coursework in military planning at the National Defense University (NDU) and, late in the year, at the Naval Postgraduate School. The NDU course gives mid-career military officers the opportunity to conceive, develop, and test (in simulations) theater-level military strategies involving combined arms and considerable operational art. This effort was led by Dr. Bennett, and the results were so successful that the course has been expanded and will be offered to the entire NDU class in the future.

The Program undertook two projects in 1987 to demonstrate capabilities of the RSAS within government settings. Patrick D. Allen led a project for the Director of Program Analysis and Evaluation that examined the use of RSAS simulation in measuring the value of force modernization in NATO's Central Region over the period 1980-1995. The project was

stimulated by the inability to represent modernization well using the traditional measures employed by OSD. It will run through most of 1988, and will familiarize PA&E analysts with the RSAS.

Dr. Schwabe led a project for OJCS that examined the potential for using the RSAS as a complement to detailed human military war gaming conducted within OJCS over a period of many months each year. The project included gaming, the play of Blue officers against an automated Red commander in a multi-theater war, and experiments in how best to discuss strategy alternatives. The project is being completed in 1988. On the basis of this experience, OJCS has decided to support a larger RSAS application in 1988 within its own facilities.

Dr. Davis led a new assessment of the NATO/Pact Central Region balance for the Under Secretary of Defense for Policy. The study employed the RSAS and demonstrated in detail the concepts of multiscenario analytic war gaming as the basis for assessments. The study included numerous observations and conclusions about improvement measures with high potential leverage, including, notably, arms control agreements incorporating limitations on the readiness of Soviet reserve forces, changes in operational planning and exercising, and several other matters.

The Program completed a study for the Director, Net Assessment, that examined possible scenarios for use in strategic-nuclear planning early in the next century when weapon systems and plausible concepts of operations may be very different from today's.

LOOKING FORWARD

As the year ended, an important transition was occurring in the Program's and Center's work: while evolutionary development of the RSAS will continue and will yield important innovations for years to come, there will be substantially greater emphasis on applications of the RSAS and on other strategy-related studies of national importance. Projects under way included efforts on conventional arms control, a net assessment of over 30 years of changes in the strategic nuclear bal-

ance (as perceived at the time and in retrospect), and a variety of RSAS-related studies. Plans were being made to study issues of long-term national strategy.

UNCLASSIFIED PUBLICATIONS

N-2625-NA, *Secondary Land Theater Model*, Patrick D. Allen and Barry A. Wilson, July 1987.

RB-6000, *Modeling Wartime Decisionmaking at the National Command Level*, Paul K. Davis, March 1987.

RB-6001-1, *The RAND-ABEL™ Programming Language*, March 1987.

RB-7801, *Analytic War Gaming with the RAND Strategy Assessment System (RSAS)*, Paul K. Davis, September 1987.

Research Highlight

MODELING COMBAT IN SECONDARY LAND THEATERS

The RAND Strategy Assessment System (RSAS) for modeling global military crisis and conflict includes a set of models for simulating combat at the strategic and operational levels. Part of the combat model set portrays warfare in Central Europe and Korea, and another part handles all other nonoceanic theaters. The secondary-theater part, described in a recent publication,¹ is representative of the distinctive features of the RSAS style of combat simulation.

Four key characteristics distinguish the RSAS secondary-theater model from other attempts to model combat:

- Use of the model parallels the establishment of a campaign plan. Key geographical features and campaign objectives must be identified, war plans have to be defined. Involvement of the user in this way ensures that factors unique to the theater influence his analysis. Most other operational-level models are more generic.
- The model emphasizes key discrete events, such as the capture of a port or mountain pass, with less detail on continuous processes such as attrition. This allows the analyst to concentrate on the military factors that promote or inhibit the event, rather than assuming the factors away with a single average probability figure.
- The model relies heavily on rules (*if-then* statements) rather than on algorithms alone for adjudicating the outcomes of battles, as well as for modeling operational decisions. The rule based approach to adjudication encourages the analyst to distinguish combat situations whose outcomes ought to be assessed by different algorithms.
- The model employs a programming language, RAND-ABEL™, that is structured for flexibility, clarity, and speed. RAND-ABEL is specifically designed to permit users to understand and change decision rules and adjudication parameters

while the model is running. These properties are either absent or less emphasized in other programming languages.

Some of the model's characteristics are illustrated by the sample of RAND-ABEL computer code shown in Fig. 9. The decision table shown is one step in the combat simulation. Each line in the table below the header is a rule that is read, "If each of the variables in the header before the slash has the value shown, then set the type of battle to the one shown here, and exit the table; otherwise, go to the next rule." The type of battle is then used in another table to determine loss rates. The user can change the values in the table, or add or subtract columns or rows.

NOTE: This table determines the type of battle that will be fought on this axis or avenue of approach. The first few lines are read as follows. If the number of defenders is less than the number required to sustain a day of battle, the type of battle is breakthrough. Otherwise, if the forward line of troops (FLOT) is between 235 and 245 km down North European axis 1, the battle is a fortified defense. If the FLOT is anywhere else on the axis and the defenders have had at least 3 days to prepare, the battle is a prepared defense.

Decision Table [Determine Type Battle]

defender- force	axis	FLOT- posit [km]	FLOT- posit [km]	prep- time [days]	type- / battle
<min-req	Any	Any	Any	Any	Breakthrough
>=min-req	NEUR-1	>=235	<=245	Any	Fortified-Def
>=min-req	NEUR-1	Any	Any	>=3	Prepared-Def
>=min-req	NEUR-1	Any	Any	Any	Hasty-Def
>=min-req	NEUR-2	>=325	<=340	Any	Fortified-Def
>=min-req	NEUR-2	Any	Any	>=3	Prepared-Def
>=min-req	NEUR-2	Any	Any	Any	Hasty-Def

[End Table]

Figure 9

Illustrative computer code from the secondary-theater model

So far, the RSAS secondary-theater model covers Scandinavia, the Baltic Islands, Italy, Turkey, Greece, and Iran. Areas to be incorporated in the near future include Yugoslavia, the Arabian peninsula, and Pakistan. Combat functions represented include force deployments, air and coastal control, air combat, coastal combat, land combat, airborne and amphibious operations, and deep operations by special forces.

¹N-2625-NA, *Secondary Land Theater Model*, Patrick D. Allen and Barry A. Wilson, July 1987.

V. Force Employment Program

Dean A. Wilkening, Director

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The Program

As its title suggests, NDRI's Force Employment Program deals with the application of military force to protect U.S. security interests. If military campaigns are to be successful, it is important that an effective array of forces and viable plans for using them be in place ahead of time. To accomplish that with its limited resources, DoD must make difficult choices as to which weapon systems to acquire in what quantities (issues of force structure) and how to allocate forces to different missions during wartime (issues of force employment). NDRI's Force Employment Program undertakes research intended to aid in making those choices.

NDRI's Force Employment Program was initiated in the fall of 1986 by grouping together several projects that had been started under other Institute programs. Since that time, additional studies have gotten under way. The projects chosen for inclusion and those begun over the past year reflect key problem areas in strategic and tactical force structure and employment.

STRATEGIC FORCES

Strategic force issues include the following:

- Ability to threaten Soviet targets.
- Strategic defense.
- Arms control.
- Command, control, communications, and intelligence (C³I).

Holding targets in the USSR at risk is an important DoD mission that spans all the Services. The greatest challenges are presented by deeply buried targets and relocatable targets (e.g., mobile missiles). While the former are being effectively addressed in research outside of RAND, the latter have proven less tractable. Institutional barriers, disciplinary boundaries, and organizational commitments to specific weapon systems have prevented the formulation of a coherent approach to the problem of strategic relocatable targets (SRTs). Because NDRI was created to bridge institutional and disciplinary barriers, the RAND FFRDC is in a good position to contribute significantly to progress on the SRT issue.

As a first step, NDRI has undertaken a project jointly sponsored by the Under Secretary of Defense for Acquisition (USDA), the Assistant Secretary of Defense (C³I), and the Director of Program Analysis and Evaluation. In this study, the NDRI project team is estimating the effectiveness of various operational concepts for holding Soviet SRTs at risk. The team will also assist in evaluating force requirements and will estimate the costs for each concept. Finally, taking all these factors into account, an overall assessment will be performed.

Sometimes strategic force structure changes not so much from a new mission to be fulfilled as from a new technology to be exploited. The President's Commission on Integrated Long-Term Strategy has pointed to the near-future prospect of missile systems capable of delivering conventional warheads within a few meters of their targets and the potential of those systems for enhancing the flexibility of deterrence. At NDRI, a research team led by Robert Lempert under USDA sponsorship has been quantitatively assessing the likely implications of such weapon systems within both the strategic and theater contexts.

Over the past year, three major projects in the Force Employment Program have addressed strategic defense issues. The Under Secretary of Defense for Policy sponsored a study comparing the U.S. costs of adding strategic-defense lasers or kinetic-kill interceptors with the Soviet costs of adding enough ICBMs to defeat those defense elements (see the research highlight following this program narrative). For the Organization of the Joint Chiefs of Staff, program staff examined the role that strategic defenses might play in enhancing nuclear deterrence and fulfilling broad U.S. national security objectives. Special attention was placed on the transition phase, during which defensive forces would increasingly supplant offensive forces as the principal military means of achieving those objectives. Herbert G. Hoover and Michael D. Miller have been working under the sponsorship of the Strategic Defense Initiative Organization to develop and apply methodologies for assessing the capability and robustness of advanced directed-energy weapon concepts for ballistic-missile defense. The recent focus of this effort has been on systems comprising ground-based lasers and orbiting

mirrors. The methodologies developed in this project have been widely adopted in the defense community.

Arms control has important implications for U.S. and Soviet force structure and employment. The dearth of research concerning those implications makes it difficult to decide whether some arms controls would be in the interest of the United States. For example, banning mobile ICBMs would make it easier to verify Soviet compliance with strategic arms reductions, but it would make it more difficult for the United States to enhance the survivability of its ICBM force. Overall reductions in ICBM forces would require rethinking which Soviet targets to hold at risk or, more basically, what constitutes adequate deterrence. Issues such as these constitute a promising avenue of research that NDRI hopes to address in the near future.

Strategic command, control, communications, and intelligence are being addressed in a pair of projects led by John H. Craigie. This work includes assistance to OJCS in developing a standardized database describing U.S. C³ systems and networks. NDRI has cohosted a series of workshops to assess the data needs and holdings of various segments of the strategic C³ community. These workshops have proved valuable in providing a forum for communications among those segments, thus improving the prospects for acceptance of standardization measures. Access to C³ data on RAND's part also helps fulfill NDRI's charter responsibility to maintain technical capabilities across a broad range of matters of concern to OSD and OJCS. The other project, sponsored by the Assistant Secretary of Defense (C³I), entails aiding in determining the most effective applications of simulation and modeling in support of C³I resource allocation. Dr. Craigie is leading a third strategic C³ project within the Applied Science and Technology Program.

TACTICAL FORCES

In the Program's work on tactical force issues, particular attention is being paid to innovative weapon systems with applications in more than one Service. For instance, it had long been planned that tactical reconnaissance would be accomplished via Air Force overflight. Recently, however, the Air Force and the Army

have been assessing the potential of high-altitude, long-range standoff sensors, and three Services have been developing unmanned drones. NDRI has undertaken a project to aid the Director of Program Analysis and Evaluation in generating a DoD-wide perspective as to what systems are needed.

Another cross-Service issue of considerable interest to OSD is that of defending against tactical missiles. NDRI has been performing a study for the USDA—this one in collaboration with RAND's Arroyo Center—that integrates previous anti-tactical-missile research performed by RAND for the Air Force and the Army. The point of the research is to evaluate the cost and effectiveness of passive and active defenses and of counterforce measures. The project leader is Charles T. Kelley, who was involved in the prior work, as were other members of the research team.

NDRI initiated the Force Employment Program as a way to provide thematic unity and direction to its efforts in this key area of defense research. But force employment considerations remain an important part of NDRI's projects in other areas, too, e.g., technology, resource management, and defense policy, where questions such as these must be faced. Would a new technology really increase strategic-defense effectiveness? Would the extra sorties generated in wartime by improved airbase resource management make a difference in the progress of the conflict? Is a policy goal of fighting two-and-a-half simultaneous wars supportable given the forces available? The higher profile given force employment issues by the new program helps ensure that questions such as those will be asked in the research conducted in other NDRI programs. But the interaction runs both ways. As indicated throughout this narrative, developments in technology and defense policy frame most of NDRI's research in force employment.

SELECTED BRIEFINGS

Maurice Eisenstein, *SDI Transition*, to the Director, Plans and Policy, Organization of the Joint Chiefs of Staff/J-5, and the Second Conference on Stability, Air-
lie House, Warrenton, Virginia.

George L. Donohue, *Implications of Near-Zero-CEP Weapons for Strategic and Theater Warfare*, to the Defense Science Board Summer Study Group on Non-nuclear Strategic Weapons.

John H. Craigie and Major James E. Leach, *Strategic C³ Modeling and Analysis*, to the 55th Military Operations Research Symposium, Maxwell Air Force Base, Alabama.

John H. Craigie et al., *OJCS Strategic C³ Database*, to the Second and Third OJCS Strategic C³ Workshops,

Washington, D.C., and Omaha, Nebraska; and personnel at Headquarters, Air Force Space Command.

Timothy Webb, *Strategic Defense Leverage, Phase II*, to the Under Secretary of Defense for Policy; the Deputy Under Secretary of Defense for Strategic and Theater Nuclear Forces; the Assistant Deputy Under Secretary of Defense for Strategic Aeronautical and Theater Nuclear Forces; and the Assistant Deputy Under Secretary of Defense for Force Analysis, Concepts, and Plans.

Research Highlight

THE COST-EFFECTIVENESS OF STRATEGIC DEFENSES

Since 1984, national security policy has held that strategic defenses would be judged desirable only if they were to be survivable and *cost-effective at the margin*. According to Ambassador Paul Nitze, a defense system meeting the cost-effectiveness criterion would have to be

cheap enough to add additional defense capability so that the other side has no incentive to add additional offensive capability to overcome the defense. If this criterion is not met, the defensive systems could encourage a proliferation of countermeasures and additional offensive weapons to overcome deployed defenses instead of a redirection of effort from offense to defense.¹

ADDRESSING THE PROBLEM

For the past three years, NDRI has been evaluating the potential of various strategic defense architectures to meet the cost-effectiveness criterion. George L. Donohue, Timothy Webb, and their colleagues simulated the effectiveness of various defense configurations at protecting U.S. military targets and estimated the costs of those configurations and of Soviet strategic offensive forces. That allowed them to identify, for each postulated engagement scenario, the defense configuration that would give high confidence of protecting U.S. military targets at the lowest possible cost. The configurations comprised different combinations of space-based and ground-based kinetic-kill interceptors (those destroying their targets through the force of impact). Figure 10 depicts the elements of a kinetic-kill architecture that could be deployed in the 1990s.

The researchers calculated the marginal cost-effectiveness of the defense configurations for various Soviet attack scenarios and levels of target protection. They estimated the cost to the United States of expanding its defense configuration enough to achieve a given level of target protection against a 20 percent increment in Soviet nuclear weapons employed. That cost divided by the cost of the Soviet weapon increment yielded a *marginal cost ratio* (MCR). The Nitze

criterion was interpreted as corresponding to an MCR of 1.0 or less.²

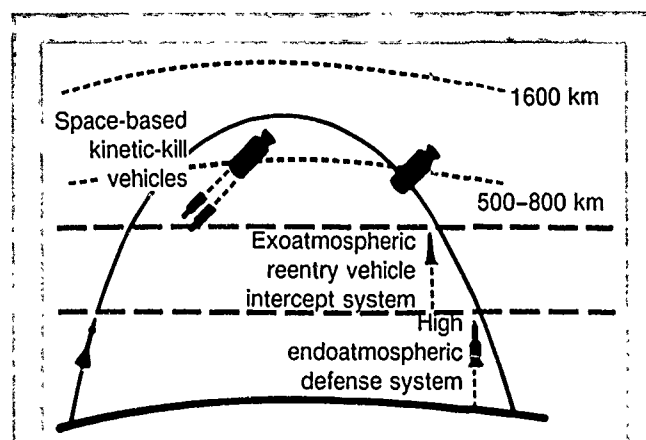


Figure 10
Example of defense architecture evaluated

WOULD THE CRITERION BE MET?

In one plausible, representative case examined in the study, it was assumed that the United States would deploy kinetic-kill defenses and that the Soviets would expand their strategic offensive forces, employing MX-equivalent technology and incorporating several types of decoys. The U.S. defense objective was to be 90 percent sure that 50 percent of the targets in each of the following categories would survive a massive Soviet nuclear strike: ICBMs; bombers and submarines; command, control, and communications (C³); military bases; ports; and military support. It was assumed that U.S. systems for passively discriminating reentry vehicles (RVs) from decoys would work well ($K = 2$).³

²This interpretation is somewhat arbitrary, as the Soviets may be able to pay less than a dollar or be willing to pay more than a dollar for every dollar that the United States spends. However, the MCR chosen to represent the cost-effectiveness criterion could be varied substantially without affecting the conclusions of the study.

³The total cost of this nominal architecture would be roughly \$324 billion (in 1986 dollars), assuming a 15-year life span and excluding the costs of research, development, testing, evaluation, and support.

¹*On the Road to More Stable Peace*, Paul H. Nitze, Department of State Bulletin, April 1985.

For this nominal case, it was found that **strategic defenses would not meet the cost-effectiveness criterion**. If the Soviets spent enough to increase their RV complement by 20 percent beyond near-parity with U.S. defenses, the United States would have to spend four times as much on additional defenses to once again fulfill its defense objective (see Fig. 11, left-most bar). Furthermore, **varying the assumptions did not change the conclusion**. Several variations were examined (see Fig. 11):

- **Scaling back the Soviet attack.** If only strategic offensive forces and C³ were to be defended, i.e., if it were assumed that the Soviets would not attack other military targets, the MCR would be less unfavorable, though not by much.
- **Scaling back the defense objective.** It might

not be necessary that 50 percent of U.S. targets survive in order to deter the Soviet Union from attacking. However, even if the objective were only 20 percent survival (with 90 percent certainty), the MCR would still be over 3.

- **Changing the ability to discriminate.** If the ability of the defenses to discriminate decoys and RVs were greatly enhanced ($K = 5$), the MCR would drop to 2. If, on the other hand, it was not possible to discriminate ($K = 0$), the MCR would be greater than 15. Obviously, the cost-effectiveness of strategic defenses is very sensitive to discriminative ability.
- **Adding Soviet antisatellite missiles (ASATs).** The nominal case does not assume the most cost-effective Soviet strategic force. If the Soviets were to develop ASATs capable of

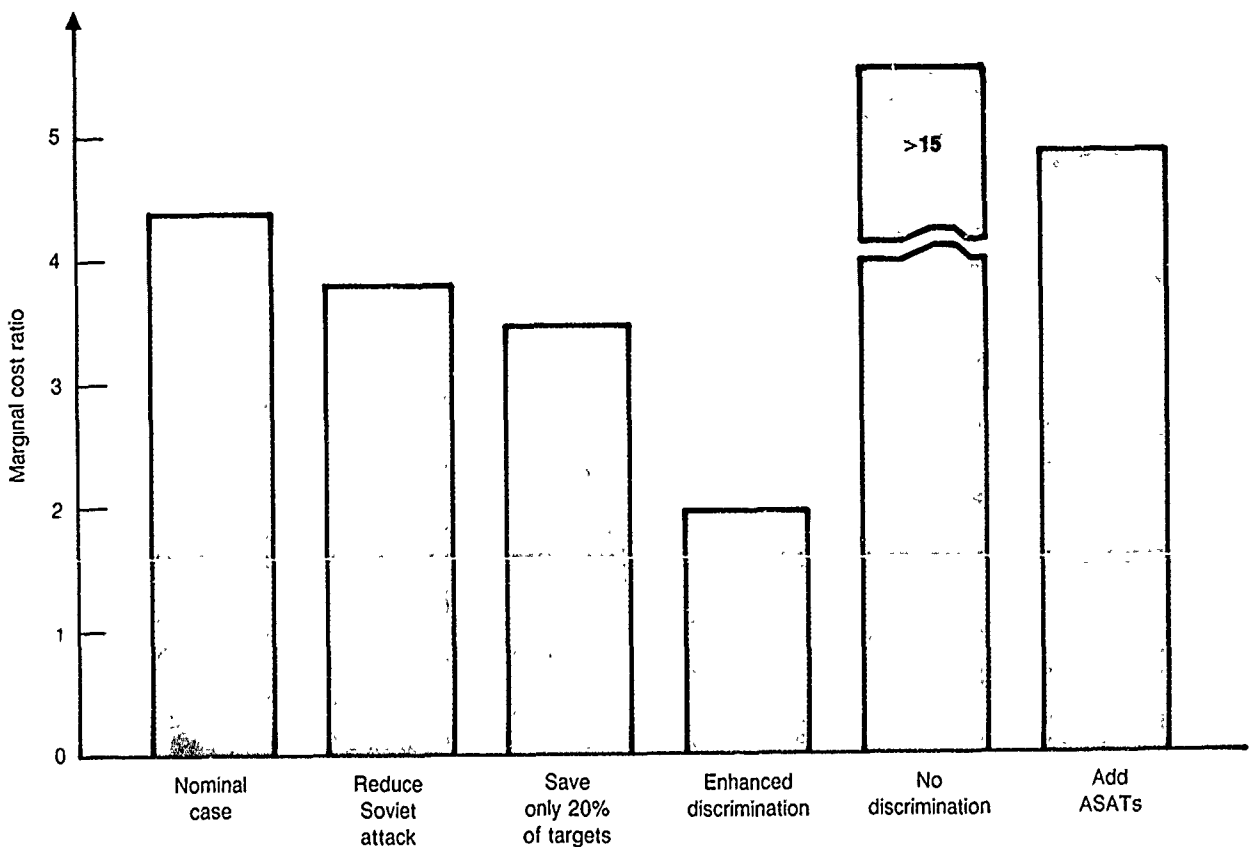


Figure 11

Marginal cost ratios for strategic defenses are unfavorable

destroying space-based defense satellites, the MCR would increase to almost 5.

LIMITATIONS AND APPLICATIONS

A study of this kind requires numerous assumptions and simplifications that limit its scope and the precision of its results. For example, U.S. defense architectures and Soviet offensive improvements were assumed to be technically feasible, economic resources were treated as unconstrained, and the conversion of Soviet costs to dollars was problematic. Nonetheless, the study clearly offers some insight into the desirability of engaging in a defense-offense competition with the Soviet Union on the scale envisioned here.

Beyond that, the analysis helped to identify three technological advances that might greatly influence defense cost-effectiveness:

1. Minimizing the warhead weight of space-based interceptors, along with the weight of the interceptor platforms (thus decreasing launch costs).
2. Automating the manufacture of space systems, to enable high degrees of production learning.
3. Improving on-orbit reliability of space systems.

Further refinement and application of the methodology employed in this study should aid in the evolution of priorities for strategic-defense research and development.

VI. Applied Science and Technology Program

Eugene C. Gritton, Director

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military support from privately owned space communication systems.

REDRESSING THE NATO-PACT ARMOR IMBALANCE

Because of the Warsaw Pact's large quantitative advantage in armored vehicles, DoD has placed a high priority on maximizing the U.S. qualitative advantage in armored-vehicle and antiarmor technology. In a major project under DARPA sponsorship, a team of NDRI analysts led by Terrell G. Covington is defining conceptual combat vehicle systems that integrate disparate advanced technologies for improving armored-vehicle and crew survivability and for enhancing antiarmor capabilities. A conceptual system has been defined for a relatively light vehicle armed with a hypervelocity missile and operated by a two-man crew with extensive artificial-intelligence support for navigation and other functions. Staff of the Institute's Information Processing Systems Program contributed to the analysis of artificial-intelligence requirements. Attention has now turned to an integrated system concept for a heavy vehicle incorporating advanced armor protection and munitions technologies. At the request of DARPA's Deputy Director for Systems and Technology, project staff also evaluated the technical maturity of the electromagnetic gun for antiarmor applications.

IMPROVING THE ACCURACY AND EFFECTIVENESS OF CONVENTIONAL WEAPONS

One general improvement to U.S. forces that would also help redress the armor imbalance is to improve the accuracy and effectiveness of conventional deep-strike weapon systems. NDRI is assisting DARPA in defining a technology program for hypervelocity weaponry. A report was issued last year on planning a national hypervelocity test facility, and attention has since turned to comparing ballistic delivery options for kinetic-energy (nonexplosive) projectiles. Delivery options have been compared for theater and regional, along with intercontinental, targets.

To enable target destruction by kinetic-energy or conventional-explosive projectiles at theater ranges and

beyond, new navigation technologies are being developed. Joseph Aein and his colleagues are assisting DARPA in evaluating the work of contractors for miniature Global Positioning System receivers and are exploring critical phenomenological limitations and performance characteristics of fiber-optic gyroscopes.

Other work for DARPA entails evaluating the use of high-power microwaves for suppressing air defenses in deep operations by attack helicopters. The same project issued a report on the susceptibility of deep-strike submunitions to microwave and laser weapons. Elements of this research have been carried out in collaboration with Project AIR FORCE, another RAND FFRDC.

Success of deep strikes and of a theater campaign in general may depend on reconnaissance by unmanned aircraft. In 1987, NDRI initiated an assessment of the capabilities of current infrared and radar sensors to meet the endurance requirements of flights intended to last for weeks or even months.

ASSESSING THE STATUS OF SOVIET RESEARCH AND DEVELOPMENT

Planning defense-related R&D requires an understanding of the accomplishments of Soviet science and technology. For many years, RAND has been reviewing the open Soviet scientific literature to apprise DARPA and the defense R&D community at large of Soviet R&D trends related to defense. In 1987, NDRI issued reports on attempts by the Soviets to restructure the administration of R&D and on Soviet research on intense relativistic electron beams (see the research highlights).

TECHNOLOGY AND ARMS CONTROL

The political and military implications of arms control are addressed in other NDRI research programs. Engineers and scientists in the Applied Science and Technology Program evaluate the technical feasibility of arms control measures and their potential effects on U.S. and Soviet technology.

In 1987, two of the Program's projects examined aspects of the proposed Chemical Weapons Treaty.

The Program

Most of the trends and alternatives examined in NDRI's research programs can be understood only within an evolving technological context. This is especially the case in considerations of force structure analyses. The employment of future weapon systems cannot be evaluated without knowing what capabilities the state of the technological art will support. Conversely, a military planner might wish he had some capability and might want to know what technological problems would have to be overcome to achieve it. But even questions of policy can turn on technological considerations. A decision whether to conclude an arms control agreement might depend on whether the technology exists to monitor or verify compliance. NDRI's Applied Science and Technology Program is explicitly concerned with the evolution of defense-related technologies.

Clearly, it would not be possible for a research program with limited resources to address all defense-related technologies. The Program's researchers are thus concentrating on a restricted set of national security objectives that would appear to be of particular defense utility and in which RAND has had considerable experience on which to build. These objectives are as follows:

- Improving the survivability and endurance of strategic command, control, communications, and intelligence (C³I) systems.
- Redressing the large armor imbalance between NATO and the Warsaw Pact.
- Improving the accuracy and effectiveness of conventional weapons.
- Expanding our knowledge of Soviet advances in defense-related technologies, including counter-measures to U.S. advances.
- Assessing the feasibility and implications of implementing arms control agreements.

These objectives draw on R&D in a variety of areas, e.g., advanced electronics for information processing, electromagnetics and communications theory, hypervelocity phenomena, and systems engineering. Again, these are areas of long-standing interest to researchers within the Program and elsewhere at RAND. To assure continued expertise, the Institute has committed

funds outside the project structure (via Research Support) to promote staff development. A seminar series on sensor analysis promotes exchange of information among the staff and between RAND personnel and visitors from other organizations. Exploratory research projects and seminars have investigated the potential of neural nets—computational devices that may enhance pattern recognition—and a variety of advances in material science.

STRATEGIC C³I

The greatest stresses on the connectivity of the national command authority would be those occasioned by nuclear attack. The Applied Science and Technology Program has undertaken several studies of strategic C³I survivability and operability.

Work continues on amplitude-modulated (AM) broadcast emergency relay, a long-term survivable-communications project headed by Edward Bedrosian and sponsored—as is much of the Program's research—by the Defense Advanced Research Projects Agency (DARPA). The project's objective is to advance the technical feasibility of using phase modulation to link as many AM radio stations as possible into a nationwide network capable of supporting vital military and governmental communications during emergency periods, including post-nuclear attack. A final report has been issued for a study of another possible component of a robust nationwide communications system—the fiber-optic lines being added to the public switched telecommunications network (see the research highlight following this narrative). That study was carried out in cooperation with the Civil Technology Program in RAND's Domestic Research Division.

Under the sponsorship of the Assistant Secretary of Defense (C³I) and the Defense Communications Agency, John H. Craigie is leading research on the national C³I architecture and on command center integration. This project is closely related to Dr. Craigie's work for the Force Employment Program. The Organization of the Joint Chiefs of Staff is sponsoring a project under Cullen M. Crain's leadership to define operational changes necessary to obtain wartime

For the Under Secretary of Defense for Acquisition, Jerome Aroesty completed an assessment of the interrelationships between reporting provisions of the proposed treaty and those already contained in domestic U.S. law regulating the chemical industry. For OJCS, Dr. Aroesty and Maurice Eisenstein are evaluating aspects of proposed treaty provisions relating to on-site inspections on demand. They are assessing the provisions' implications for the protection of sensitive defense and industrial information and the possibilities of loss (or gain) from treaty-induced technology transfer.

Program staff are examining two other treaties—the recently concluded Intermediate Nuclear Forces Treaty and the Comprehensive Test Ban Treaty, now under consideration. In the first instance, the Assistant Deputy Under Secretary of Defense (Strategic, Aeronautical, and Theater Nuclear Systems) asked NDRI to assist in developing an INF inspection protocol. In the second case, a thorough evaluation of the national security effects of a comprehensive test ban is being carried out for the Assistant to the Secretary of Defense for Atomic Energy.

OTHER RESEARCH

Although strategic defense is not a principal thrust of the Applied Science and Technology Program, staff are assisting the Strategic Defense Initiative Organization in the mediation of Red-Blue team interactions within the Organization's Technical Countermeasures and Soviet Response Program. Along the offensive dimension of the strategic competition, Bruno W. Augenstein is assessing possible future intelligence requirements for supporting a U.S. initiative to hold at risk strategic mobile or relocatable targets. This project supports the integrative research on strategic relocatable targets that is being pursued within NDRI's Force Employment Program.

INTERDIVISIONAL COOPERATION

Examples of collaboration with Project AIR FORCE and with RAND's Domestic Research Division have been cited. As the Program's research agenda evolves, cooperative ventures with RAND's Army-sponsored

Arroyo Center will be added. For example, the Program plans to shift the emphasis in its U.S.-USSR technology analyses from Soviet research in science and technology to the countermeasures the Soviets might develop and field in response to U.S. technological advances. Considerable collaboration with the Arroyo Center is envisioned in assessing Soviet responses to U.S. deep-attack initiatives. Further work is expected in the application of systems engineering to armor-antiarmor issues. This will present opportunities for NDRI-Arroyo force employment work ranging beyond the line-of-sight orientation of NDRI's current research in that area to encompass indirect fire, including terminally guided submunitions.

UNCLASSIFIED PUBLICATIONS

R-3463-DARPA, *Soviet Research on the Transport of Intense Relativistic Electron Beams Through High-Pressure Air*, Nikita Wells, May 1987.

N-2612-DARPA, *Soviet High-Technology Restructuring Drive: The MNTK Network*, Simon Kassel, August 1987.

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Jerome Aroesty, *Chemical Warfare Treaty Issues*, to Commander, U.S. Army Chemical School.

Terrell G. Covington, *Future Combat Vehicle Concepts*, to Deputy Director, Systems and Technology, DARPA.

E. C. Gritton, *Overview of Applied Science and Technology Program*, to Deputy Director, Research, DARPA; Deputy Director, Systems and Technology, DARPA; Principal Deputy Assistant Secretary of Defense (C3I).

Simon Kassel, *Soviet Directed-Energy Weapons Development*, to Acting Chief Scientist, Strategic Defense Initiative Organization.

Simon Kassel, *Soviet Potential for the Development of Advanced Technologies: A Progress Report*, to Director, Technology Assessment and Long-Range Planning Office, DARPA.

G. A. Sears, *Hypervelocity Weaponry. Theater Strike Weapon*, to Director, Strategic Technology Office, DARPA.

Research Highlight

BARTERING FOR A MORE SURVIVABLE COMMUNICATIONS NETWORK

Amid the widespread devastation that would follow a nuclear war, surviving pockets of population and elements of government would seek information about medical services, food, and the extent of damage. A telecommunications infrastructure would be patched together with whatever is left of the old one, from two-way radios to surviving segments of the public switched network. In fact, enough of AT&T's current nationwide coaxial-cable system has been hardened against the effects of nuclear attack to provide a survivable border-to-border communications skeleton. However, it is uncertain how much longer this hardened system will remain in operation. The coaxial-cable network is now almost 25 years old, and commercial carriers have been laying fiber-optics lines that are more cost-effective—but unhardened.

As a result, the National Communications System, which is charged with restoring domestic telecommunications in emergencies, has been considering other options for promoting communications survivability. One of those options is to induce commercial carriers to harden enough of their planned intercity fiber optics lines to contribute to postattack communications connectivity. The carriers might do that at no cost to the government in return for something they would value—access to the Interstate highway rights of way (ROWs), which they cannot now obtain. Enabling such a barter is not trivial, because the ROWs are owned by the states, not the federal government. For an analysis of the feasibility of a survivability-access barter, the National Communications System and the U.S. Department of Transportation turned to NDRI.¹ The RAND team, headed by Ronald W. Hess, addressed the two principal aspects of the barter bearing on its feasibility: institutional barriers to establishing as many links as possible meeting uniform hardness standards, and the economic attractiveness of the Interstate ROWs to the carriers.

¹See R-3500-DOT/NCS, *Feasibility of Using Interstate Highway Right-of-Way to Obtain a More Survivable Fiber-Optics Network*, Ronald W. Hess et al., January 1988.

INSTITUTIONAL BARRIERS

The analysts examined three approaches to promoting connectivity and uniform hardness:

- Pursuing voluntary federal/state cooperation.
- Inducing state cooperation by tying federal highway aid to a state's granting of access.
- Compelling cooperation through the congressional power of eminent domain.

The first option is the most politically attractive, but the chances of its yielding many links appear doubtful because so many state highway administrators oppose loosening access restrictions. They worry that installation and maintenance of utility lines along the ROWs could give rise to traffic hazards and disruptions. They also foresee costs to the state if utility lines have to be moved for road work or if they are damaged by state transportation crews.

It might be possible to allay those concerns in the case of fiber-optics lines. The latter can be laid quickly and require little maintenance. Costs can be controlled through contractual arrangements or fees. However, highway officials would still be reluctant to grant an exception to fiber optics for fear that other, less benign utilities would demand equal treatment. The RAND analysts believe that a valid legal case could be made for discriminating in favor of fiber optics, but highway administrators think otherwise.

From a practical standpoint, the two remaining options are both likely to produce a number of uniformly hardened links. Both, however, require congressional approval, and it is not possible to estimate their political support.

ECONOMIC ATTRACTIVENESS

In the absence of any consideration rendered to the government, access to Interstate median strips would afford carriers a savings of \$12,000 per mile of utility installation, compared to the next best alternative—installation along railroads (compare cases A and B in Fig. 12). Government stipulations could cut into that \$12,000 in three ways.

Research Highlight

A SOVIET ATTEMPT TO PUT RESEARCH TO WORK IN INDUSTRY

Advanced technology in the USSR has chronically lagged far behind Western achievements primarily because the Soviets have not succeeded at industrial application of the results of advanced scientific research. This failure is the result of organizational problems and economic disincentives.

As part of its current economic reform, the USSR has established a new type of scientific-industrial organization, the interbranch science and technology complex, known as the MNTK (its Russian acronym). The purpose of this new organization is to manage the entire evolution of a given technology from basic research to the construction of prototypes that can be introduced into mass production. To learn more about the purpose and potential of these organizations, Simon Kassel of NDRI reviewed and analyzed the relevant Soviet literature. His findings follow.¹

MNTKs have been designed to overcome the institutional barriers between science and industry by uniting elements of the Academy of Sciences, which is responsible for much of the USSR's advanced research, with production components of the industrial ministries. They have also been granted special economic powers and privileges. They have priority in the provision of resources and can demand additional funding above that specified in the five-year national economic plan if required by changing circumstances. They can nego-

tiate directly with government ministries, enter into separate contracts with other communist countries, and sell their production directly abroad.

Within one-and-a-half years of their enabling legislation, 23 MNTKs had been created for technologies ranging from anticorrosion, advanced crushing and pulverizing, and powder metallurgy to automated control systems, light conduits, and eye microsurgery. Some incorporate dozens of scientific research institutes together with large industrial enterprises.

However, despite their numbers, size, and powers, MNTKs seem to be failing at all the problems they were designed to overcome. Even Soviet observers feel that the outlook for the MNTK network as the primary means of improving Soviet advanced technologies is not encouraging. In many cases, little has been done beyond establishing an MNTK. Attempts by the MNTKs to procure resources and facilities and to enforce their economic powers have met with the usual bureaucratic resistance. The industrial ministries apparently lack the incentive to cut production enough to retool and experiment with new technologies.

The Soviet leadership does not seem to understand that the conservative Soviet ideology of production is incompatible with the revolutionary nature of advanced technology. The technologies chosen for MNTK establishment have been more suited to improving existing processes and machines than to developing advanced materials and devices. But most importantly, MNTKs cannot address the lack of competition and other economic disincentives to innovation that are inherent in the Soviet system.

¹See N-2612-DARPA, *Soviet High-Technology Restructuring Drive. The MNTK Network*, Simon Kassel, August 1987.

First, about \$7000 per mile would be required to assure that vulnerabilities to nuclear attack are largely alleviated, e.g., through burying cable and other system components and providing back-up generators (cases D and E in Fig. 12). That amount could be substantially higher if more complete alleviation were required (case F)—or somewhat lower if less were needed (case C). Second, many states require some payment to help compensate for the costs and perceived disadvantages of allowing utilities on highways. Those payments have varied from \$5000 (cases D and E) to \$10,000 per mile (case F) for installing other utilities along non-Interstate rural toll roads. A number of states do not require such compensatory payments (cases B and C).

Finally, if the states insisted on installation at the ROW fence line instead of on the median, savings would be about \$4000 less (cases E and F).

The carriers might thus net a maximum of \$8000 a mile (case C), or some 15 percent of their total construction cost, through installation within the Interstate ROWs in exchange for increased survivability of the lines. In all likelihood, however, net savings would be considerably less—if there were any. And all this assumes that the railroads, which charge about \$12,000 per mile for access to their ROWs, do not lower their own fees to compete with the Interstates.

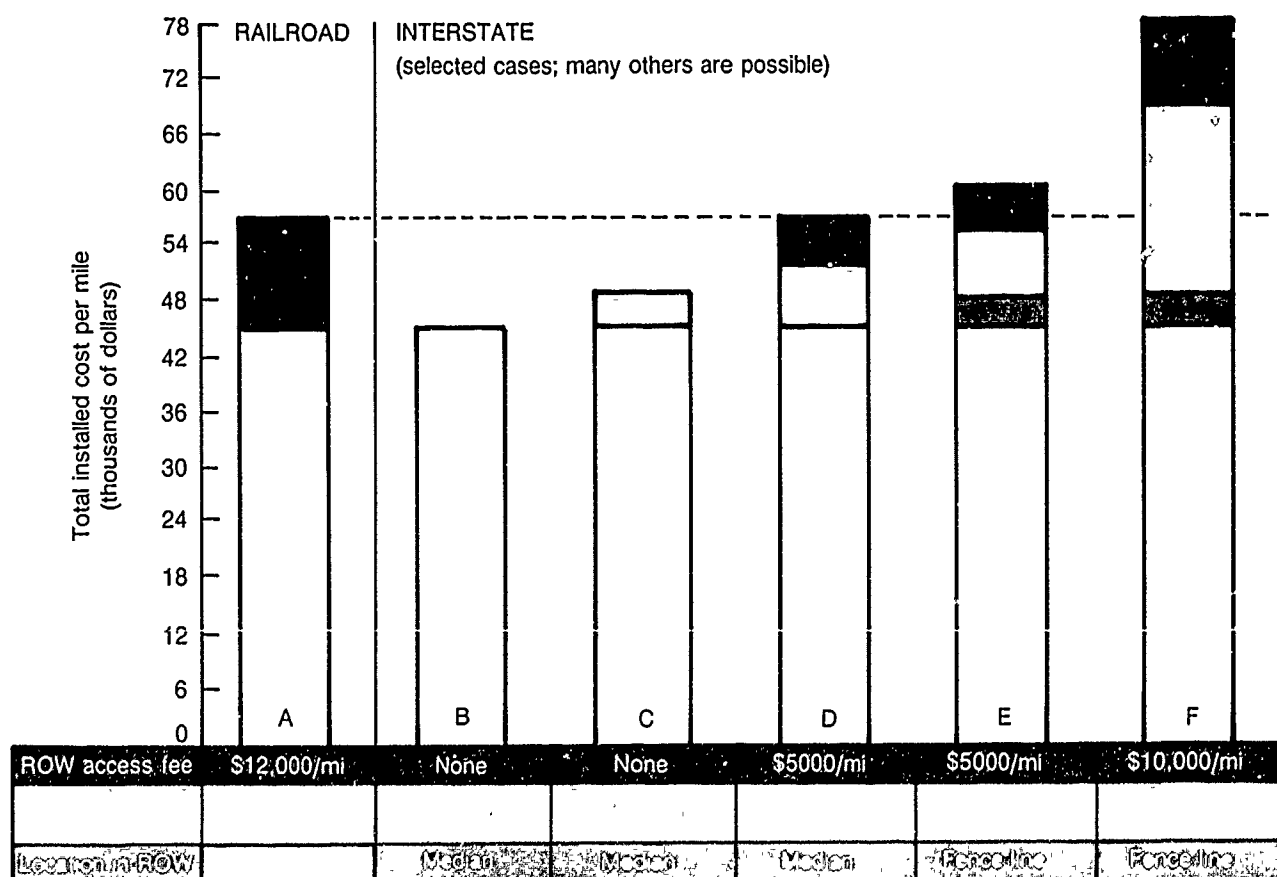


Figure 12

Savings from installation along Interstates are cut into or reversed by government requirements

Research Highlight

SOVIET RESEARCH ON INTENSE RELATIVISTIC ELECTRON BEAMS

For many years, the Defense Advanced Research Projects Agency has been funding RAND studies of Soviet research in areas having potential applications to defense technology. One topic that has drawn NDRI's attention has been that of intense relativistic electron beams (IREBs), such as those that might be used in charged-particle-beam weapons. Of particular military interest is the ability to propagate an IREB over a long distance without the benefit of the external magnetic or electric fields that might be used to focus it in a confined commercial facility, e.g., in controlled fusion. Research is being conducted on IREB propagation at pressures corresponding to those found in both the upper and lower atmospheres.

Nikita Wells has been reviewing Soviet open sources in physics to gain a better understanding of Soviet IREB research.¹ His review indicates the Soviets have been devoting considerable effort to problems of IREB propagation and have exhibited a marked understanding of the problems involved. Their findings seem to match U.S. observations on such topics as the plasma channel created by passage of an IREB through air, the air pressure ranges that maximize beam transport efficiency, and the effect of various beam instabilities on propagation.

The amount of Soviet research reported on IREB propagation changed rather dramatically in the mid-1980s. In the preceding 10 years, the amount of research had steadily increased. Since 1983, there has been a pronounced upswing in research on propagation through low-pressure air, while reports on propagation at higher pressures have fallen off sharply over the past few years. These trends, together with the disappearance from the open literature of key researchers, are indicative of censorship. They also may imply a shift in the sophistication of research on higher-pressure propagation to a level that the Soviets believe to be of military significance.

On the basis of those indications and of the reports in the open literature, it appears that Soviet research on IREBs is at least as advanced as that under way in the United States and other Western nations. NDRI is continuing to monitor the Soviet open scientific literature for clues as to the status of their research in this and other defense-related areas.

¹R-3309-DARPA, *Soviet Research on the Transport of Intense Relativistic Electron Beams Through Low-Pressure Air*, Nikita Wells, August 1986, and R-3463-DARPA, *Soviet Research on the Transport of Intense Relativistic Electron Beams Through High-Pressure Air*, Nikita Wells, May 1987.

VII. Information Processing Systems Program

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***Evaluating Tools Used in Building Expert Systems* 66**

The Program

Over the past 40 years, the Department of Defense has been both a catalyst and an exploiter of advances in the information sciences. During that time, The RAND Corporation has worked in partnership with DoD in extending the state of the art in information systems and in adapting this technology for defense purposes. NDRI's Information Processing Systems Program provides the organizational focus for the continuation of that partnership.

SIMULATION

Researchers in the NDRI Program have been concentrating on improving the technology of simulation. Simulation is one of the primary modeling tools used by analysts to study phenomena or systems of interest. In traditional simulation, a system's components and the interactions among them are described mathematically to allow tracing the system's behavior over time. This behavior can be varied by changing the specified scenario and by varying certain factors randomly as the simulation proceeds.

Military analysts routinely simulate conflicts ranging from engagements between small units on the battlefield to strategic nuclear exchanges. Simulations are also employed to assess potential command and control problems and to analyze resource and personnel management alternatives.

Despite their ubiquity, traditional simulations, like other analytical tools, have their shortcomings. One of the most important is that they have not been readily understandable, modifiable, or manageable for analytic purposes by experts in the field of interest. This lack of transparency has often made it necessary to have a programmer mediate the interaction between the subject-area expert and the simulation, making it difficult for the expert to validate the simulation and draw reliable conclusions from it.

To increase transparency, many designers of simulations have in recent years adopted an *object oriented* paradigm. In this paradigm, traditional programming constructs (such as variables and arrays) are replaced by *objects*, which naturally represent the real-world objects being modeled (for example, airplanes or

ground radar sites). Interactions among real-world objects (for example, airplanes communicating with one another) are naturally represented by *messages* among *objects*. This makes it easier for the domain expert to identify objects in the simulation and verify or modify their characteristics.

Another promising set of improvements involves the application of *knowledge-based* techniques to simulation. These entail representing some of the domain expert's knowledge explicitly in the simulation, for example, as rules and facts that are both meaningful to the expert and interpretable by the simulation system. This can help the system explain its behavior, leading to more easily validated simulation.

Both of these improvements are under active development and application in the Information Processing Systems Program. Indeed, most of the Program's research in 1987 was devoted to the application of knowledge-based techniques to object-oriented simulations. This work is organized into two major multiyear projects and is sponsored by the Defense Advanced Research Projects Agency (DARPA). In establishing such long-term projects, DARPA and NDRI recognize the gradual nature of progress in these difficult areas and the FFRDC's responsibility, as expressed in its charter, to respond to OSD's long-term needs. It is anticipated that the Program's research in this area will eventually result in high payoffs for simulation and modeling throughout the defense community.

In one of the projects, Jeffrey Rothenberg and his colleagues are developing a number of knowledge-based techniques to make simulations more powerful and comprehensible. They are researching techniques for intelligent exploration and explanation, i.e., allowing users to modify both the model and the course of events in a simulation and making simulations explain their behavior in useful ways. They are developing ways of building models that can reason about themselves. Such models could answer questions like "What set of conditions will produce a given result?" or, more specifically, "What factors determine whether a radar detects a penetrating aircraft?" or "Which events can cause a penetrator to alter its flight plan?" Specific topics addressed during 1987 include the representation

of causality, the ability to vary a simulation's level of aggregation (so it could work, say, at the battalion, brigade, or division levels), and a new approach to sensitivity analysis.

A related task in a different project resulted in a July publication, *Building Learning and Tutoring Tools for Object-Oriented Simulation Systems*. In this task, an air battle simulation was equipped with facilities that made the simulation's behavior more easily inspectable by student users. (See the research highlight following this narrative.)

In the second major project, Stephanie Cammarata and her colleagues are using knowledge-based tools to enable the transparent use of large heterogeneous external databases in object-oriented simulations. Integrating external databases poses many problems in compatible representation of data and knowledge, maintaining consistency with local databases, and inferring requisite knowledge that is omitted from the external database. For example, project staff have developed an *intelligent information dictionary*, which allows the user to browse through elements of a database and which recognizes omitted information and reports invalid or inconsistent data. The dictionary facility is being applied to data on air order of battle that is used in many of RAND's simulation projects, including the RAND Strategy Assessment Center, which is operated through NDRI's Strategy Planning and Assessment Program.

In an effort closely coordinated with its work on knowledge-based simulation, the Program is facilitating the transfer of simulation research results into RAND's military simulation laboratories and eventually into the DoD and Service communities. This effort, undertaken by James R. Kipps, is on the development of an object-oriented programming language that will be fully functional for military analysis and architecturally advanced enough to allow simulation researchers to explore new modeling techniques.

Stephen Bankes is reviewing issues relevant to the support of distributed war gaming and simulation, i.e., games and simulations in which the players are in different locations. It is anticipated that such configura-

tions will play an important role in the war games of the next decade. This research has emphasized the definition of issues that need to be addressed to ensure successful long-term development of distributed simulation. In particular, issues relating to standard protocols and model quality have been stressed. A workshop on this topic held at RAND in October was attended by 85 persons, including representatives of the Army, the Air Force, the Organization of the Joint Chiefs of Staff, DARPA, other DoD agencies, universities, and commercial laboratories. The project has entailed considerable coordination with the other RAND FFRDCs.

EXPERT SYSTEMS

Another program focus is on expert systems, which are coming into increasing application in military acquisition, logistics, tactics, and other defense areas. An expert system consists of a knowledge base (again, rules and facts) and a facility for drawing inferences from that knowledge. This gives it the ability to solve problems (and explain its behavior) by applying expertise in much the same way that a human does.

As a first step toward evaluating the software tools used in building expert systems, RAND published a two-volume report on that topic in 1987. The report offers an evaluation framework that was reviewed by tool developers and users at NDRI workshops conducted the previous year. (See the research highlight.)

Program Director Iris Kameny is leading an effort sponsored by the Assistant Secretary of Defense (Production and Logistics) to develop a preliminary guide to the management of expert systems. The guide is intended to assist DoD managers in determining the applicability of expert systems technology to many of the problems within the P&L community. It will address expert system development as a software engineering endeavor and will show how expert systems can be developed using accepted software development methods and standards.

Because it is dedicated to supporting research methodologies in a variety of defense applications, the Information Processing Systems Program is a natural locus for coordination of activities among projects in various

RAND research programs and FFRDCs. In addition to the examples cited above, the Program is beginning a project in collaboration with the Defense Manpower Research Center to develop a prototype computerized decision support aid for estimating the costs of changes in the Active/Reserve balance. Further cooperative research ventures are anticipated.

UNCLASSIFIED PUBLICATIONS

R-3443-DARPA/RC, *Building Learning and Tutoring Tools for Object-Oriented Simulation Systems*, David McArthur, July 1987.

R-3448-DARPA/RC, *The New ROSIE® Reference Manual and Reference Guide*, James Kipps, Bruce Florman, Henry Sowizral, June 1987.

R-3542-DARPA/RC, *Evaluating Expert System Tools: A Framework and Methodology*, Jeffrey Rothenberg et al., July 1987.

N-2603-DARPA, *Evaluating Expert System Tools: A Framework and Methodology—Workshops*, Jeffrey Rothenberg et al., July 1987.

N-2660-DARPA, *Why Is It Difficult To Program in Von Neumann Languages?* Sanjai Narain, November 1987.

SELECTED BRIEFINGS

Steven Bankes, *Technology To Support Distributed Wargaming and Simulation*, to the RAND Workshop on Distributed Warfare Simulation.

Stephanie Cammarata and Iris Kameny, *Intelligent Databases for Simulation and Modeling*, at the Minnowbrook Conference on Database Machines and Artificial Intelligence.

Iris Kameny, *Simulation Research at RAND*, to the Defense Science Board Panel on Computer Applications for Training and Wargaming.

Jeffrey Rothenberg, Iris Kameny, Stephanie Cammarata, *IPS Program, Highlighting the Knowledge-Based Simulation and Intelligent Databases Projects*, to the Director, Technical Assessment and Long-Range Planning Office, DARPA; personnel of the DARPA Information Science and Technology Office; OASD (Reserve Affairs); OASD (C³I); the U.S. Army Concepts Analysis Agency; the U.S. Army Human Engineering Laboratory; the Jet Propulsion Laboratory; the Swedish Defense Materiel Administration; Los Alamos National Laboratory; Lawrence Livermore National Laboratory; Weapons Systems Research Laboratory; and the Australian Department of Defense.

Research Highlight

BUILDING LEARNING AND TUTORING TOOLS FOR SIMULATION SYSTEMS

Computerized simulations have long been useful tools for designing and evaluating complex systems. As such, simulations often contain considerable practical knowledge regarding the systems being modeled. In recent years, there has been a growing interest in making that knowledge more accessible so that simulations could be used in training.

NDRI has been investigating and exploiting the tutoring potential of SWIRL, a strategic air-battle simulation, by equipping it with computer-based tools and techniques that could help students in military strategy courses learn about the objects and behaviors involved. The aim has been to provide an environment in which students who are relatively naive about computers and military strategy can learn through practice to make strategic decisions at least as well as the simulation's own simple expert systems.¹

SWIRL was developed at RAND in the early 1980s. It was chosen for the tutoring project because of RAND's familiarity with it and because it is a simple but rich application in which the embedded strategic knowledge is well defined but challenging to learn. Furthermore, SWIRL is an object-oriented system, i.e., the simulation proceeds through the interaction of components representing integral, concrete objects (bombers, radars, missiles). This modular organization of system knowledge facilitates the kind of coherent, local changes that are necessary for learning through experimentation and practice.

ADAPTING THE SYSTEM

Developing the learning environment required modifying some of SWIRL's characteristics and adding facilities to the system. For example, SWIRL had to be altered to allow the training version to distinguish between properties of objects that ought to be modifi-

able by the student and those that represent physical constants or are not relevant to the strategic issues being taught.

Two kinds of facilities were added to SWIRL to support the process of generating and testing a strategic idea:

- **Tools to help establish a strategic problem to test.** In the SWIRL learning environment, students can create whole new defensive configurations or offensive strategies by editing previous ones. Object parameters can be redefined interactively through SWIRL's graphical display. To provide some direction in choosing a configuration or strategy to test, the learning environment maintains for each strategic configuration a record of wins, losses, and opposing configurations tested.
- **Tools to understand the results of a simulation.** A simulation can be interrupted at any point to allow the student to examine the current state and try to understand why the simulation is proceeding as it is. "Snapshots" of previous states can also be recalled. Study of snapshots is facilitated by a "browser" that allows the student to inspect the underlying behaviors and parameters by pointing at objects and menu items on the computer screen. In the example shown in Fig. 13, the student has pointed to a filter center (where radar reports are integrated) and selected one menu item that displays communication links and another that asks for a description of the center. In the list of variables describing the center, the student now points to "COMPUTING-DELAY" to see the definition shown in the box below the description. Key simulation snapshots, along with comments by the student, can be stored in the experiment history maintained by the environment.

The learning environment created for SWIRL does not constitute an active tutor; it does not control the tasks on which students work or determine the pace of interaction. The SWIRL "tutor" is a passive, exploratory learning environment whose facilities are used only at the student's initiative.

¹R-3443-DARPA/RC, *Building Learning and Tutoring Tools for Object-Oriented Simulation Systems*, David McArthur, July 1987.

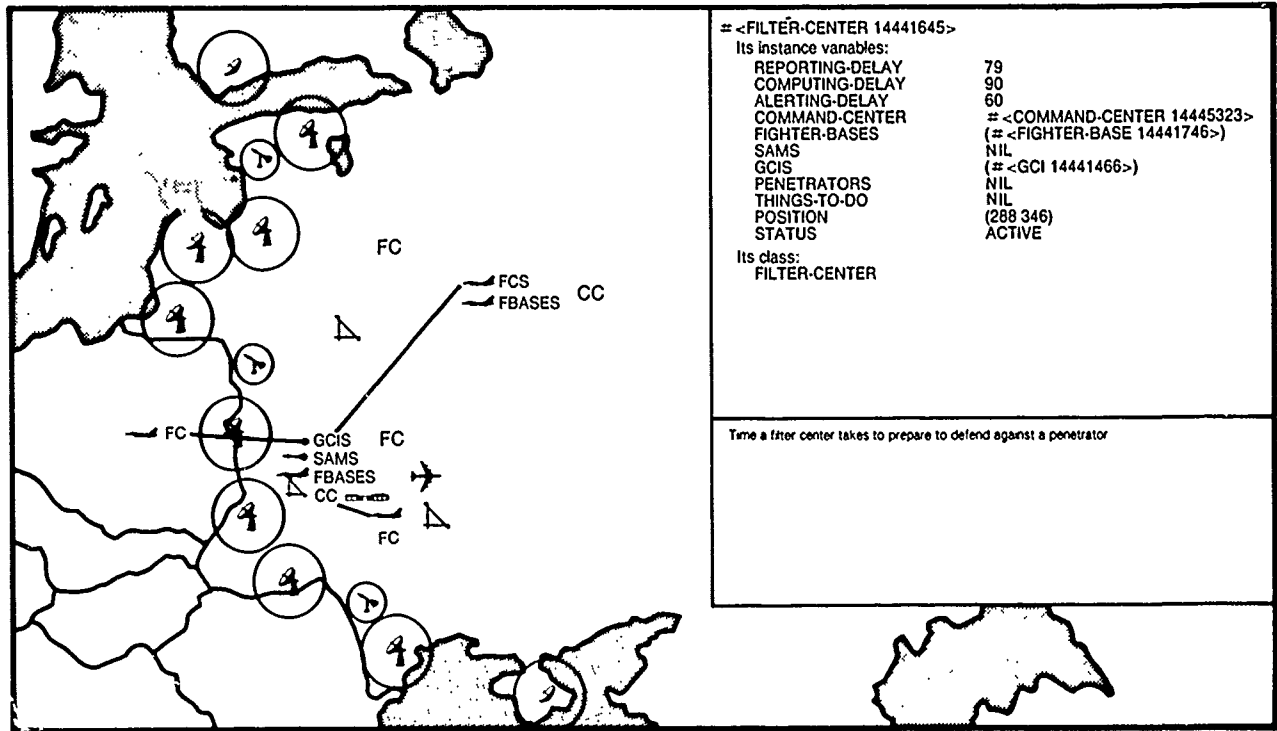


Figure 13
Sample SWIRL screen, showing use of the browser

LESSONS FOR TOOL-BUILDING

Passive tools could have wide applicability in probing the activities of dynamic systems such as simulations. Builders of passive learning environments in diverse domains might benefit from the guiding principles developed while constructing the SWIRL tools:

- It should be easy for the learner to construct a wide range of models to examine. In the SWIRL environment, students create new strategies and configurations by simplistic editing and combination of old ones. The next step might be to extend the flexibility of these tools while maintaining their simplicity.
- The models constructed must be inspectable. Inspectable models are crucial to learning and tutoring in many areas, because they permit students to examine model components and understand the reasons for the model's overall behavior. If models are to be meaningfully inspectable, they must be semantically faithful to the real-world entities being modeled.
- The learners should have tools that help them control exploration. Because students can construct a wide range of models, including many of marginal educational value, they may waste a lot of time in unprofitable exploration. The SWIRL environment's annotation and recall facilities can help direct students' experimentation. More effort needs to be expended in developing techniques with that objective.

Research Highlight

EVALUATING TOOLS USED IN BUILDING EXPERT SYSTEMS

Developments in artificial intelligence have permitted the construction of computerized systems that can apply expert knowledge to help solve real-world problems. Expert systems are used to address issues in manufacturing resource allocation, scheduling and configuration, military acquisition, and diagnosis and classification tasks.

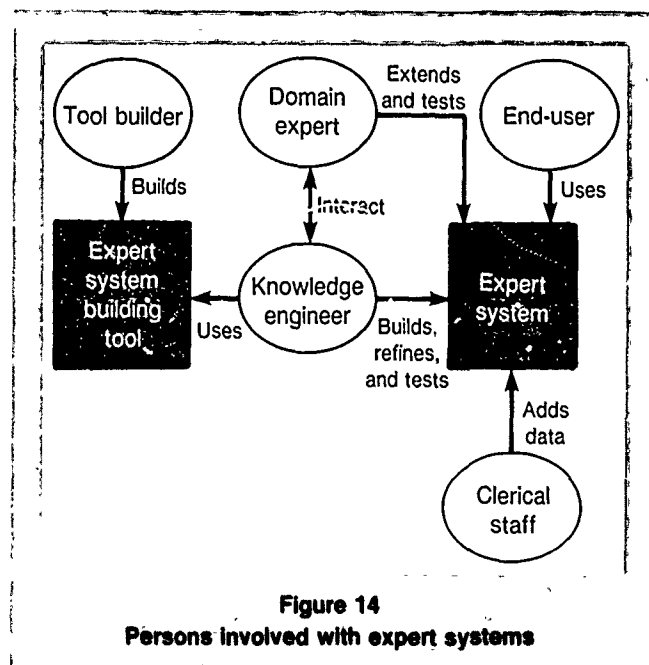
An expert system is a program that consists of two basic parts—a *knowledge base* and an *inference facility*. The former contains knowledge (e.g., facts, rules, strategies) drawn from experts in the domain of concern (e.g., logistics, tactics). The inference facility is a subsystem that can derive conclusions from the knowledge base, allowing the system to solve problems in much the same way that a human expert does. Because they make explicit the knowledge on which their decisions are based, expert systems should be easier to understand and validate than traditional software

An expert system is built by a *knowledge engineer*, i.e., someone who understands the domain and can turn that understanding into a working program. The knowledge engineer interacts with domain experts to encode knowledge, elaborate a prototype system, and iteratively test and refine it (see Fig. 14). Each of these steps is facilitated by the use of special programs or languages, which are referred to as expert system *tools* or *shells*.

Tools for use in developing expert systems are typically large, complex systems in themselves, requiring major investments of time, money, and effort to realize their full advantage. It is thus important that the tools chosen be a good fit for the job at hand. However, choosing appropriate tools is often difficult. A knowledge engineer faces a plethora of tools with different objectives. Guidelines for evaluating and selecting expert system tools would be extremely helpful.

Under the sponsorship of the Defense Advanced Research Projects Agency (DARPA), information scientists from NDRI reviewed available tools, surveyed tool and system developers, and developed an evalua-

tion framework. They held workshops for tool and system builders to discuss the framework and learn more about the concerns of those groups. The results of the study are as follows.¹



A NEW FRAMEWORK AND METHODOLOGY FOR TOOL EVALUATION

Prior attempts at evaluating tools have been limited in scope and thoroughness. The new framework will help evaluators set out their criteria more explicitly and account for all factors that are potentially relevant to tool selection. It can be applied to tools that have not yet appeared on the market, and it should aid in developing new tools. The framework calls for identifying and considering each of the following:

1. **Application characteristics**—the nature of the problem to be addressed and the project that is to address it. These characteristics include the nature of the problem domain, the available sources of expertise,

¹R-3542-DARPA, *Evaluating Expert System Tools: A Framework and Methodology*, Jeffery Rothenberg et al., July 1987, N-2306-DARPA, *Evaluating Expert System Tools. A Framework and Methodology—Workshops*, Jeffery Rothenberg et al., July 1987.

the set of development tasks to be undertaken with the tool, and the project's budget.

2. **The contexts** in which the tool is to be used.

These correspond to the phases of system building, i.e., conceptualizing, prototyping, development, delivery, maintenance.

3. **The tool capabilities**—e.g., handling uncertainty, controlling inference, explanation—that are relevant to the specified application characteristics and contexts. Capabilities are likely to be a more helpful basis for evaluation than specific features listed by the tool developer, because seemingly equivalent features in different tools may provide different capabilities.

4. **Metrics**—or the specific criteria to be used in evaluating the tools. Applicable metrics may include cost, flexibility, clarity, efficiency, vendor support, and extensibility (which includes breadth of applicability and ease of integration). The importance of each of the metrics varies with the phase of development.

5. **Assessment techniques**—ways to apply the metrics to the tools (e.g., to decide what capabilities are actually present). Information sources that are helpful in applying metrics include published lists of capabilities, published test applications (benchmarks), and interviews with other tool users.

The first step in applying the framework is to define each of the items listed above for the case at hand. Next, the evaluator identifies those tools that fulfill the required capabilities and that meet any other absolute constraints, such as cost. **The metrics can then be applied via the assessment techniques to evaluate the capabilities of the tools to function in the required contexts, given the application characteristics under consideration.**

The NDRI framework is intended to help in organizing the evaluator's thoughts. The specifics of its application must be elaborated in each instance. At present, the ability of an evaluator to apply such a framework is limited by the availability of relevant information sources. Building and maintaining databases of published case studies or benchmark solutions would require considerable work and cooperation on the part of tool users and vendors. An alternative would be to

create an organization to assume this responsibility, preferably one funded by a government agency such as DARPA or by a consortium of tool user groups.

THE STATE OF THE ART

The research team's discussions with tool builders and users revealed **the pivotal position of software engineering in expert system development.** Building an expert system is as much an attempt to solve questions of representation, integration, debugging support, and so on, as an effort to resolve knowledge- and domain-related issues. Indeed, the failure of most tools to support integration within hardware and software environments is a critical impediment to the construction of expert systems that have to be embedded in other systems, as is the case in some DoD projects.

The overwhelming majority of tool users are convinced that **the tools are well worth the expense and that vendors are generally helpful and supportive.** Of course, the tools do have some drawbacks. For example, many tool users feel that, for most rule-based expert system tools, the indeterminate order in which the rules are invoked makes it difficult to specify intended sequences of events. Also, some tools may be released prematurely; users strongly prefer learning a tool only after it has been freed of bugs. Finally, expert system tools may not be worth the investment where speed (of execution) or flexibility is required. Projects that are amenable to algorithmic solutions may always be executed more efficiently in traditional procedural languages, and some projects have special requirements that argue for in-house tool development.

The lessons learned from expert system development are contributing in important ways to software engineering in general. Expert system development represents a shift away from the traditional approach to software engineering that begins with requirements analysis and proceeds through subsequent phases with little or no mechanism to back up and rethink. The use of rapid, iterative prototyping may eventually increase software productivity and effectiveness in general. DoD software acquisition standards should be reexamined to accommodate this approach.

VIII. Acquisition and Support Policy Program

John L. Birkler, Director

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RAND has a long history of research on acquisition and logistics, sponsored principally by the Air Force. In 1986, RAND began to place more emphasis on resource management issues faced by OSD and OJCS. By the end of 1987, those agencies had initiated sponsorship of enough acquisition and support policy projects to merit the establishment of a formal research program in this area. With the new program, NDRI hopes to enhance the systematic, coherent development of research themes and methodologies in acquisition and logistics and draw more attention at the national level to the importance of research on DoD-wide issues of resource management.

ACQUISITION POLICY

Defense acquisition—the development and procurement of military systems—is a matter of widespread and increasing concern in the United States. Congressional hearings, government reports, and articles in the press suggest that the acquisition process is not working well: that development fails to produce systems that work satisfactorily, that major systems incur large cost overruns and experience long delays, and that parts are overpriced. Research suggests that the criticisms of defense acquisition are in many instances exaggerated. Nevertheless, if U.S. forces are to be modernized, substantial improvements must be made throughout the acquisition process, from research and development through demonstration and validation, full-scale development, and production.

Three NDRI projects are addressing the acquisition problem across a broad front. Giles K. Smith and his colleagues are identifying procedures and regulations that may have constrained the ability of the defense industry to innovate and respond quickly to DoD's needs. The first phase of the work entailed a review of how regulation was growing and affecting the acquisition process (see the research highlight following this narrative). The second phase, now under way, is directed to determining the most powerful factors affecting the length of the acquisition process, identifying reforms that might shorten the process, and assessing the side-effects of those reforms. This project, like most of NDRI's work on acquisition, is sponsored by

the Under Secretary of Defense for Acquisition (USDA).

A second research team is studying intra-European cooperation in developing, producing, and procuring weapons. The team is assembling several databases to assist in identifying trends in European weapons collaboration and the forces underlying those trends. These trends and forces will be examined more closely in a study of a specific illustrative weapon program. The eventual goal is to identify ways in which the United States might benefit from intra-European cooperation.

The objective of the third project, led by James N. Dertouzos, is to extend and apply methods of microeconomic analysis, including analysis of non-market resource allocation, to infer lessons for improving the acquisition process. This research, sponsored by the Director of Program Analysis and Evaluation (PA&E), has drawn on the expertise of economists from a variety of organizations. A Conference on the Economics of Defense Procurement was held at RAND in February 1987; the research team has cosponsored and participated in other conferences; and consultants at the University of Arizona conducted an economic experiment testing the effects of alternative procurement mechanisms. The experiment and the conference interactions have contributed to papers on profit policy, contractor selection and contract execution, and promoting competition through teaming.

Other research on acquisition examines specific phases of the process. For example, in work for the Assistant Secretary of Defense (Production and Logistics (P&L)), RAND analysts are contributing to the formulation of criteria for deciding which weapon systems should go through a prototype phase prior to full-scale development. In a congressionally mandated study sponsored by the USDA, Program staff are performing the most extensive quantitative analysis yet of DoD's support of independent research and development (IR&D) by defense contractors. The purpose is to determine whether IR&D stimulates increased investment in R&D by the contractors themselves. Researchers are studying several recent foreign projects, such as Israel's Lavi aircraft, as well as numerous American programs.

One of RAND's most influential acquisition projects to date reviewed the acquisition strategy for a single critical weapon system—the advanced-technology (“stealth”) bomber (ATB, now the B-2). Representative Les Aspin, Chairman of the House Armed Services Committee, sponsored an amendment to the 1988-1989 Defense Authorization Bill that required an assessment of the adequacy of DoD's acquisition plan for the ATB. The project was formally initiated by the USDA in June 1987.

The research team was headed by NDRI Director Michael D. Rich and included John L. Birkler, who now directs the Acquisition and Support Policy Program, other RAND analysts, and several OSD analytical personnel led by Milton Margolis, then Deputy Director, Resource Analysis, PA&E. One objective of the project was to determine whether competition would enhance the cost-effectiveness of producing the ATB airframe, producing major subsystems, and integrating, assembling, and checking out the total system. The results of the study were briefed to Secretary of Defense Caspar Weinberger, Mr. Aspin, Senator Sam Nunn, and numerous senior OSD, Air Force, and congressional policymakers. NDRI's recommendations were accepted by OSD, and the Institute has been asked to participate in monitoring their implementation.

The research summarized here is concerned primarily with the procedural and institutional aspects of acquiring weapon systems. It complements work carried out in the Applied Science and Technology Program and in the Force Employment Program, whose findings about technical feasibility, capability, and force effectiveness influence decisions regarding which weapon systems to acquire. It also builds on work carried out in RAND's Domestic Research Division concerning cost growth, schedule slippage, and performance shortfalls in pioneer industrial plants and other large-scale commercial enterprises.

COMBAT SUPPORT POLICY

Cross-divisional ties characterize NDRI's research on support policy. Logistics has been a central concern of RAND's Project AIR FORCE for years, and, more recently, has been taken up for the Army within

RAND's Arroyo Center. The topics studied within NDRI address the special concerns of OSD and OJCS.

A principal emphasis of RAND's work in materiel management has been the importance of accounting for uncertainty in planning for wartime. RAND has consistently recommended that management systems be made flexible enough to function under a variety of theater- and tactical-level contingencies regarding enemy threat, disruptions in the combat support system, and lapses in command, control, and communications. It is insufficient to plan for a “best estimate” scenario (a conclusion also reached in studies conducted by the Strategy Planning and Assessment Program).

David Kassing heads a project that addresses both acquisition and logistics. Its goal is to help ensure that planning for the acquisition of conventional munitions will be valid and responsive enough to promote wartime sustainability. So far, the project team has reviewed and evaluated the models used by the various Services to estimate how much of each type of munition might be required during a conflict. Now the project staff is beginning to consider how requirements determination might account for the uncertainty of combat and how munitions logistics systems might help overcome the effects of unexpected developments. This project, like the others on support policy (with one exception), is sponsored by the Assistant Secretary of Defense (P&L).

Mr. Kassing and his colleagues have initiated work on a second project stemming from correspondence early in 1987 between the USDA and the Under Secretary of the Army. The two Under Secretaries expressed their concern regarding the ability of DoD's entire materiel distribution system to function in wartime. They called for a broad-scale, critical review of “physical distribution in its broadest sense” and requested NDRI to conduct it under P&L sponsorship. The review began in interviews with 45 DoD distribution officials inside and outside the Services to obtain a preliminary overview of problem areas. The interviews suggested three analytical tasks, two of which are now being undertaken: developing long-run options for supporting the mobilization and deployment of forces and assessing

possibilities for integrating the systems that distribute such supplies as spare parts, fuel, and munitions.

A major study for the Organization of the Joint Chiefs of Staff is examining how planning and management of wartime logistics resources by the Unified Commands is to be linked to their planning and management of combat operations. The project team, led by Craig Moore, has been considering the need for specific means of reporting and assessing the changing information that could contribute to wartime decisionmaking by the theater Unified Commands.

Other logistics research is looking at the problem of uncertainty for an important element of the parts and materiel management system—the maintenance depot. The research team, led by Thomas F. Lippiatt, is determining the difference between maintenance activity levels at Air Force depots and the corresponding maintenance requirements that had been projected during budgeting. After assessing the reasons for those differences, the team will suggest ways of improving the projections. This project benefits from extensive RAND experience in depot demand research under Project AIR FORCE.

Acquiring a weapon system implies a commitment for support resources, and one of the Program's studies is attempting to quantify that commitment. Project staff are examining ways to allocate support costs to specific weapon systems. By using tactical aircraft as an example, the team can draw from experience gained in the other NDRI research (and Project AIR FORCE work) on depot maintenance.

UNCLASSIFIED PUBLICATIONS

N-2599-ACQ, *Aerospace Weapon System Acquisition Milestones: A Data Base*, M. B. Rothman, October 1987.

N-2638-ACQ, *A Review of European Arms Collaboration and Prospects for Its Expansion under the Independent European Program Group*, Terrell G. Covington, Keith W. Brendley, Mary E. Chenoweth, July 1987.

SELECTED BRIEFINGS

I. K. Cohen, *Research Topics for Study of Future DoD Materiel Distribution System*, to Deputy Assistant Secretary of Defense (Logistics); Special Assistant to the Assistant Secretary of Defense (Production and Logistics); and Deputy Director for Plans, Concepts, and Analyses, OJCS/J-4.

Terrell G. Covington, *Project Status, Two-Way Defense Trade and Results of Discussions with IEPG Representatives from the United Kingdom, France, Germany, and Spain*, to Assistant Deputy Under Secretary of Defense (International Programs).

Paul T. Hill, Arthur J. Alexander, and Susan J. Bodilly, *Analysis of IR&D Program. Preliminary Results*, to Acting Under Secretary of Defense (Research and Engineering); Commander, Army Materiel Command; and Office of Management and Budget staff.

Craig Moore, *First Steps Toward Joint/Combined Logistics Research at RAND*, to Director of Logistics, OJCS/J-4; Principal Deputy Director, PA&E; and Director of Logistics Plans, Headquarters, U.S. Air Force.

Michael D. Rich, John L. Birkler, et al., *Managing Cost and Risk in the Advanced Technology ("Stealth") Bomber Program*, to Secretary of Defense; Under Secretary of Defense for Acquisition; Assistant Secretary of Defense (P&L); Assistant Secretary of Defense (Comptroller); Director, Defense Advanced Research Projects Agency; Director, Program Analysis and Evaluation; Director, Operational Test and Evaluation; Deputy Under Secretary of Defense (Strategic and Theater Nuclear Forces); Military Assistant to the Secretary of Defense; National Security Council staff; Secretary of the Air Force; Under Secretary of the Air Force; Assistant Secretary of the Air Force (Acquisition); Vice Chief of Staff, U.S. Air Force; Commander, Air Force Systems Command, Chairman, House Armed Services Committee; Chairman, Senate Armed Services Committee; and House and Senate Armed Services Committee staffs.

Research Highlight

REGULATION AND WEAPON ACQUISITION

Many managers and executives responsible for conducting weapon acquisition programs argue that the process is overregulated. Both in industry and in the Department of Defense, it is widely believed that rigorous enforcement of an expanding body of regulation is seriously inhibiting the timely and economical development of weapon systems. There is, however, little unambiguous and systematically documented evidence of the penalties claimed to result from this regulatory environment. Anecdotes and assertions abound, but hard, quantitative evidence is surprisingly sparse.

In 1986, the Under Secretary of Defense for Research and Engineering asked NDRI to identify the extent of growth in the regulatory structure controlling weapon acquisition, along with the effects of those regulations on weapon system performance, cost, and acquisition scheduling.¹ Emphasis was to be placed on quantitative information, however limited in scope, that might contribute to a better understanding of the issues.

As a first step in assessing the effects of regulation, the NDRI researchers interviewed a number of administrators—program managers, contract officers, and acquisition officials—in industry, government, and the military services. The dominant, persistent theme sounded by those interviewed was that an increasingly troublesome set of administrative obstacles prevented them from accomplishing their program objectives in a timely and efficient manner.

In an effort to verify the claims of increasing regulatory burden, the research team assembled a variety of

measures of regulatory activity spanning the last 10 to 25 years. The picture that emerged was unclear. Some institutions have increased their activity. For example, the congressional staff working on procurement issues has grown; Congress introduces more restrictions in defense authorization and appropriation bills each year; and the number of procurement-related documents published for the Congress by the General Accounting Office has increased. But the staffs and activities of other organizations have remained essentially constant. This avenue of analysis thus provided only limited support for the assertion that weapon acquisition is subject to increasingly burdensome levels of regulatory controls.

The acquisition officials interviewed indicated that regulatory activity generally did not affect the performance of the weapon systems developed. However, they did claim that regulation affected costs, and their estimates in that regard were consistent. Drawing from those estimates and sparse data from other sources, the research team hypothesized a probable regulatory cost burden ranging from 5 to 10 percent of total program costs. Effects on acquisition schedule were more ambiguous, although there is some evidence that the time required for acquisition has increased marginally over the last couple of decades.

The NDRI researchers were thus not able to draw definitive conclusions as to the effects of regulatory activity on acquisition. However, the lack of convincing evidence in support of broad regulatory effects should not be taken to imply that such effects are small or do not exist. They simply could not be identified within the scope of this initial research.

NDRI is now engaged in the next phase of the study. The objective of the current work is to identify the factors most responsible for the length of the acquisition process, allowing a better understanding of what reforms might be necessary to accelerate it. Side effects of those reforms will also be assessed.

¹When DoD was reorganized, sponsorship passed to the Under Secretary of Defense for Acquisition. The methods and findings of the initial phase of the study are documented in R-3578-ACQ, *A Preliminary Perspective on Regulatory Activities and Effects in Weapon Acquisition*, G. K. Smith et al., December 1987.

IX. Defense Manpower Research Center

Glenn A. Gotz, Director

The Program

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The Program

The resolution of policy, strategy, and force employment and modernization issues depends in some sense on the resolution of manpower issues. The effective employment of new technologies on the battlefield implies a higher level of education and training than might have been necessary in previous wars. DoD's operating and support costs depend on the seniority and skill levels of its support personnel. If better management of maintenance and repair activities is to decrease weapon system down times, there must be an ample source of skilled repairmen. The successful execution of military strategies depends on the elusive characteristic of readiness, which is a function of the quality, quantity, and training of armed forces personnel. If issues such as these are to be resolved, several broad questions must be answered:

- How many persons with what characteristics are required?
- How can those persons be obtained?
- How can those obtained be retained in the force, and how will the force evolve as a result?
- What are their capabilities, and how might those capabilities be improved?
- How might the quality of life for military personnel be improved?

Those questions are addressed within RAND's Defense Manpower Research Center, which was established in 1976 and incorporated into NDRI when the latter was created in 1984.

As each of the questions cited above could be applied to either the Active forces or the Reserves, the sponsors of the Center's work include both the Assistant Secretary of Defense (Force Management and Personnel) and the Assistant Secretary of Defense (Reserve Affairs). Indeed, these two OSD elements fund the great majority of the Center's work.

All of the principal manpower research questions are faced by each of the Services. The issues taken up by the Center are those of specific concern to OSD, i.e., problems that might be addressed by OSD policies or that involve coordination among the Services or between the Services and OSD. Although many of the Center's projects focus on single Services, they gen-

erally do so as test cases for issues of DoD-wide concern. We now take a closer look at the specific problems taken up by the Center during the past year under each of the broad topic areas cited above.

REQUIREMENTS

Manpower requirements are determined by the Services under policy guidance from OSD. The Defense Manpower Research Center has examined issues of Service-OSD coordination and has performed analyses that could support more uniform application of requirements methodologies by the Services and a better understanding of the costs of requirements.

A project led by Frank Camm, for example, has been examining the characteristics and limitations of requirements policymaking in OSD. The next step will involve case studies to further elucidate that process and to address issues of Service responsiveness and OSD's monitoring of Service compliance. Another study entailed developing measures of management effectiveness at satisfying personnel authorizations, taking into account the potential for substitution of personnel in one grade or skill for those in another. Staff also developed a method to implement the performance measures. In a project cosponsored by the Director of Program Analysis and Evaluation and the Assistant Secretary of Defense (FM&P), Center staff are developing improved methods for estimating the costs of manpower policy changes. A simple model to estimate cost consequences of changes in manpower requirements is being devised.

PROCUREMENT

Recruitment of military personnel can be viewed as taking place within a labor market. The market can be characterized by aggregate supply trends. The suppliers are young adults whose decisionmaking can be modeled economically. The consumers are recruiters who procure personnel for the military and whose behavior in response to incentives and other factors can also be modeled. Each of these aspects of the labor market must be understood if recruiting resources are to be efficiently managed, and each is being addressed within the NDRI Center.

Aggregate Supply Trends

A declining youth cohort and changes in the civilian economy may have serious implications for military recruiting. Lee A. Lillard has been analyzing those and other trends affecting the demand for and supply of young people's labor. The goals are to develop measures of youth labor market conditions that would be useful for enlistment supply models and to develop the capability of determining possible adverse effects on recruiting.

Individual Supply Decisions

A number of the Center's projects during the past year have addressed decisionmaking by individuals. One of the projects examines factors affecting women's decisions to enlist, identifies promising segments of the female recruiting market, and analyzes women's service and occupational choices and their success in remaining in the military. Success in remaining is an important aspect of procurement policy in general; the Services would rather not admit persons who will drop out during their first terms. Center staff have examined the relationships among cohort quality, Service personnel policies, and attrition. A recently published report analyzes enlistment and attrition decisions jointly (see the research highlight following this narrative).

The other projects on individual decisionmaking address decisions to join or leave the Reserves. One takes competition between the Active forces and the Selected Reserves into account in estimating the effects of enlistment bonuses, differences between civilian and military pay, and other factors on accession decisions by individuals with no prior military service. The Center is also extending its previous work on determinants of attrition of non-prior-service reservists.

Few manpower studies, however, have looked at individuals with prior military service, though they make up half the Reserve complement. Sheila Kirby and M. Susan Marquis are analyzing prior-service accession and attrition to identify types of individuals with high propensities to enlist and remain in the Reserves. Results of this analysis should prove valuable in the design of enlistment incentive programs and retention

policies. A second project objective is to document the match or mismatch between the military occupational specialty assigned to an enlistee and the person's skill qualification at the time of separation; this has important implications for Reserve readiness and cost.

Demand Factors

Work by James N. Dertouzos has demonstrated the importance of taking into account such "demand factors" as recruiter quotas and incentive systems in explaining enlistment patterns. In previous years, the Center's research on this topic focused on Army recruiter management; recently, more attention has been paid to the Navy.

Dr. Dertouzos is extending this research in an effort to estimate the relative cost-effectiveness of different levels and types of recruiting expenditures. Project staff have reviewed the results of DoD's Advertising Mix Test, which tested the relative effectiveness of Service-specific and joint military advertising. Attention has now turned to developing methodologies for estimating the cost-effectiveness of different recruiting resources for increasing the supply of high-quality recruits. By accounting for attrition, reenlistment, and Reserve accession to come up with a total-man-year cost-effectiveness measure, this project shares the orientation of other recent Center research toward total-force management.

RETENTION AND FORCE EVOLUTION

Once individuals have enlisted in the Active force or the Reserves, the Services have much to gain by retaining them for successive terms, as opposed to replacing them with untrained recruits. However, personnel managers are not only interested in how to retain desired personnel but in how the force evolves as a result of individual retention and separation decisions and what all that will cost.

Center staff are developing a model to estimate the effects of reenlistment bonuses, Armed Forces Qualification Test scores, and other variables on reenlistment decisions. Additional work last year addressed the narrower, practical problem of assisting OSD in establish-

ing uniform guidelines for the Services to follow in allocating reenlistment bonuses among critical skills. The Center developed computer software that can be used in implementing the guidelines.

The Center's research has indicated that the enlisted force is aging, which has cost implications that may require offsetting policy initiatives, such as separation pay or other measures to increase midcareer separation. Center staff are incorporating newly developed costing methodologies into projection models for application to various scenarios of force evolution. Policy recommendations will be inferred from the analysis.

Center Director Glenn A. Gotz and David W. Grissmer, the Center's deputy director, are leading a project on the Reserves for the Quadrennial Review of Military Compensation. Project staff have completed models that project changes in the experience structure of each of the six Reserve components over the next decade, assuming present personnel policies continue. Further work will permit prediction of manpower structure under alternative scenarios, e.g., different retirement systems, taking into account the implications of various compensation tools—e.g., reenlistment bonuses, retirement pay—for Reserve retention. On a finer scale, project staff are also examining the effects of incentives and other unit-level factors on how fully units are manned. Drawing from these analyses, Drs. Gotz and Grissmer will recommend changes in the compensation system that should help solve Reserve manpower and training problems.

In a project cosponsored by FM&P, Reserve Affairs, and the Organization of the Joint Chiefs of Staff, Dr. Grissmer is integrating his Reserve component models with Active force projection models, including flows of personnel between Actives and Reserves. The result will be a *total force* projection model. Under the sponsorship of the PA&E, OJCS, and FM&P, Dr. Gotz has developed improved methods for assessing the costs of altering the Active/Reserve balance by adding units or transferring them between Active and Reserve components. The Center has been collaborating with the Information Processing Systems Program to automate those methods for use on computer workstations. This research builds on the Center's previous analysis of

costs associated with force mix decisions affecting Reserve units (see the research highlight).

CAPABILITIES

How do the capabilities of defense personnel and units compare with each other and with those needed, and how might they be improved? The Defense Manpower Research Center is addressing this question in studies of both civilian and military personnel.

Comparisons and Incentives

Costing techniques developed for one of the Center's requirements projects are being applied in a study of the comparative cost-effectiveness of military, civil service, and contractor personnel at performing various defense functions. Led by Adele R. Palmer, this project entails the collection of field data on the manning and performance of a set of functions by military and civilian workers. Bruce R. Orvis and other staff members are designing and evaluating a demonstration to test how the productivity of civilian DoD employees is affected by personnel practices, work environment, and sharing in the cost gains from improved performance. A survey to measure employee attitudes toward their work environment was devised during contract year 1987. Surveys in test and control sites have since been administered, and the demonstration is now under way.

Two projects seek to relate unit capabilities to defense needs. One of these is an assessment of models intended to estimate the effect of maintenance manpower on availability of weapon systems. In the second, Dr. Grissmer and his colleagues have been evaluating the capabilities of Selected Reserve units to discharge their increasing share of the defense mission. Project staff have assessed the relationship between low unit skill levels and mismatches between personnel and unit specializations. The project is now shifting to an examination of the relationship between training shortfalls and unit readiness.

Training

The most obvious way of improving the capabilities of military personnel is through training. Three of the

Center's projects are solely concerned with training issues. The major effort in this area is the Army Communications Training Experiment, directed by J. Michael Polich and John D. Winkler. The experiment's purpose is to test the benefits of an interactive, computerized video system for training military personnel in high-technology communications specialties. One test measured how classes that used the system differed in practice time and student performance from those that did not. A second test is substituting the video system for actual equipment to determine if proficiency can be held constant at a cost savings of 80 percent. This project demonstrates the value of controlled experiments in general for measuring possible efficiency gains from new training technologies. Such experiments could be undertaken for other systems or by other Services.

The other two training projects lay the groundwork for further substantive research in two important topic areas. One identified the types of data that would have to be collected to permit evaluation of the effectiveness of personnel training programs. The other identified institutional problems in administering training to members of the Individual Ready Reserve and outlined a plan for collecting information and deciding among options for improving the process.

QUALITY OF LIFE

There is some evidence to suggest that the quality of life experienced by military personnel and their dependents has a bearing on decisions to remain in the Service and on the morale—and thus the readiness—of personnel. The Center is studying two important factors related to quality of life—health care and education. Both of these topics have been taken up in cooperation with research programs operated within RAND's Domestic Research Division.

One of NDRI's largest projects to date is a collaboration with the Health Sciences Program to evaluate a demonstration of an initiative for reforming the Civilian Health and Medical Program of the Uniformed Services (CHAMPUS; see the research highlight).

Arthur Wise of RAND's Education and Human Resources Program led a study to evaluate the congressionally mandated transfer of the military's so-called "Section Six" schools to local districts. The Section Six schools were established in the early 1950s to educate the children of military personnel where local schools were judged to be unsuitable. Project staff canvassed reactions to the transfer by all groups involved and recommended alternatives. Recommendations were also made with respect to the criteria DoD should use in setting funding levels for the schools, in case a full transfer is not made. Specific implementation analyses have been completed for several of the schools, and others are under way.

CONCLUSION

The Center's agenda is changing. For many years, the emphasis was on personnel procurement, which was also the primary concern of manpower planners in the early years of the All-Volunteer Force. Now, as careerists signing on in those early years approach retirement, as the force evolves in unexpected ways, and as more sophisticated weapon systems demand more expert personnel for their operation, the Center is examining a broader palette of issues. As these new studies come to completion, their results will provide a better foundation for responsive manpower policy in the years to come.

UNCLASSIFIED PUBLICATIONS

R-3492-RA, *Cost Analysis of Reserve Force Change: Non-Recurring Costs and Secondary Cost Effects*, John F. Schank, Susan J. Bodilly, A. Allen Barbour, May 1987.

R-3510-FMP, *Military Enlistment and Attrition. An Analysis of Decision Reversal*, John Antel, James R. Hosek, Christine E. Peterson, June 1987.

N-2535-RA, *Individual Ready Reserve Skill Retention and Refresher Training Options*, Susan J. Bodilly et al., July 1987.

N-2647-HA, *Plan for an Evaluation of the CHAMPUS Reform Initiative*, Susan D. Hosek et al., July 1987.

SELECTED BRIEFINGS

Jonathan K. Cave, *Measuring the Performance of Manpower and Personnel Inventory Management Systems*, to Staff, Office of the Assistant Secretary of Defense (FM&P); and Staff, Air Force Academy.

James N. Dertouzos, *Joint Advertising Mix Test*, to Principal Deputy Assistant Secretary of Defense (FM&P); and Director, Office of Accession Policy, OSD (FM&P).

Glenn A. Gotz, *Highlights of RAND's Recruiting Research*, to U.S. Army Recruiting Research Coordination Conference.

Glenn A. Gotz, *Overview of the Defense Manpower Research Center*, to Principal Deputy Assistant Secretary of Defense (Reserve Affairs).

David W. Grissmer, *Early Attrition in the Army Guard and Army Reserve*, to Principal Deputy Assistant Secretary of Defense (Reserve Affairs); and Chief, U.S. Army Reserve.

David W. Grissmer and Jennifer Kawata, *Reserve Compensation Issues*, to Staff, Quadrennial Review of Military Compensation.

Sheila Nataraj Kirby and M. Susan Marquis, *Accession and Attrition of Prior-Service Reservists*, to Principal Deputy Assistant Secretary of Defense (Reserve Affairs); Deputy Assistant Secretary of Defense (Reserve Manpower and Personnel), and U.S. Army Recruiting Research Coordination Conference.

David Menefee-Libey, *OSD Policy on Manpower Requirements and Authorizations: An Analysis of the Directives and Instructions*, to Principal Deputy Assistant Secretary of Defense (FM&P); Deputy Assistant Secretary of Defense (Resource Management and Support); and Director, Productivity and Civilian Requirements, OASD (FM&P).

Adele R. Palmer, *Measuring the Costs of Military Personnel for Policy Analysis*, to Director, Productivity and Civilian Requirements, OASD (FM&P); and Director, Force Structure and Support Cost Analysis, PA&E.

John D. Winkler, *Applications of Interactive Videodisc in Army Training*, to Principal Deputy Assistant Secretary of Defense (FM&P).

John D. Winkler, *Army Communications Training Experiment*, to Principal Deputy Assistant Secretary of Defense (FM&P); Principal Deputy Assistant Secretary of Defense (Reserve Affairs); Deputy Assistant Secretary of Defense (Readiness and Training); Director, Training and Education, Office of the Assistant Secretary of Defense (FM&P), Director, Defense Training and Performance Data Center; Assistant Secretary of the Army (Manpower and Reserve Affairs); Commandant, U.S. Army Signal Center; and Chief, Faculty Development, Army Signal School.

Arthur E. Wise, *The Transfer of Section Six Schools. Balancing Federal, State, and Local Responsibilities*, to Deputy Assistant Secretary of Defense (Family Support, Education, and Safety).

Research Highlight

WHAT CHARACTERIZES THOSE WHO ENLIST IN THE ARMED FORCES AND THOSE WHO LEAVE EARLY?

Recruiters might be better able to target their efforts if they could tell who was more likely to enlist—and less likely to leave before his term was over. Manpower planners might be able to formulate more cost-effective policies to discourage attrition if they could predict the attrition propensity of a cohort based on its characteristics at enlistment. For the past several years, James R. Hosek and his colleagues at the Defense Manpower Research Center have been examining the determinants of enlistment behavior among young men.¹ Their most recent research extends their analysis to attrition and evaluates aspects of the relationship between enlistment and attrition.²

The new analysis, performed on a larger database from the same year of entry (1979), confirms the results of the Center's prior research on enlistment determinants. Factors such as education expectations, employment status, and academic ability are significantly associated with decisions to enlist, and those associations can be considerably different for high-school seniors and non-student high-school graduates (see Fig. 15).³

Similar factors affect an individual's propensity to quit early (or the Service's propensity to discharge him),

though not necessarily in analogous ways. Seniors, for instance, are less likely to enlist than graduates, but they are also less likely to leave once they are in (see Fig. 16). Expectations of further education are associated with different enlistment decisions for seniors and graduates but apparently work against attrition among members of both groups who do choose to enlist (see Figs. 15 and 17). Length of entry delay while waiting for a desired occupational specialty is also negatively related to likelihood of leaving early. On the other hand, employment instability before enlistment is positively related to attrition propensity among graduates. The latter findings may reflect greater success on the part of those who are more assiduous and persistent planners or who are better able to predict their "job" satisfaction.

¹See R-3238-MIL, *Enlistment Decisions of Young Men*, James R. Hosek and Christine E. Peterson, July 1985, and R-3350-FMP, *Educational Expectations and Enlistment Decisions*, James R. Hosek, Christine E. Peterson, and Rick A. Eden, March 1986.

²R-3510-FMP, *Military Enlistment and Attrition: An Analysis of Decision Reversal*, John Antel, James R. Hosek, and Christine E. Peterson, June 1987. Attrition alone was examined in a somewhat less disaggregated fashion in R-3069-MIL, *Analysis of Early Military Attrition Behavior*, Richard Buddin, July 1984 (a one-sheet summary is available as RB-2001/1). Ongoing work by Dr. Buddin addresses attrition of high-quality recruits and enlistment and attrition among women.

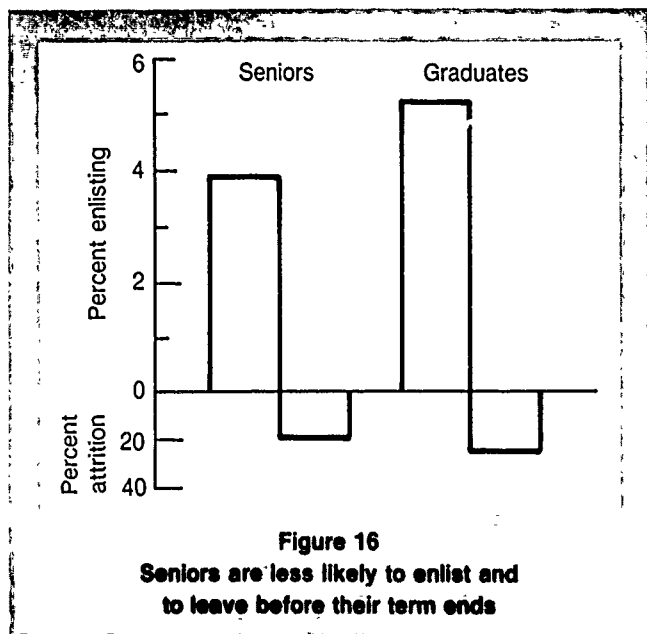
³High-school dropouts were excluded from the analysis. High-school seniors and graduates are the primary source of "higher-quality" enlistees.

	Effect on			
	Enlistment		Attrition	
	Senior	Graduate	Senior	Graduate
Academic ability (AFQT score)	-			-
Expects more education	-	+	-	-
Months of entry delay	x	x	-	-
Months since school	x	-	x	
Currently unemployed	-	-	x	x
Months since employment	+	+	x	x
Employment instability	x	x		+
Some postsecondary education	x	-	x	
Black ethnicity	+	+		

LEGEND

- + Significant positive effect
- Significant negative effect
- No significant effect
- Favorable manpower result
- Unfavorable manpower result
- x Not applicable or not measured

An effect is "significant" if there is at least a 95% probability that it did not occur by chance.



Recruiters can increase the likelihood of obtaining ultimately successful enlistees if they pay particular attention to combinations of attrition determinants. For instance, consider a person with an unpromising set of characteristics—a graduate who experienced employment instability and a brief entry delay and who did not expect more education. Such an individual would be 3.5 times more likely to leave before the end of an initial three-year term than a senior with the opposite attributes (see Fig. 17). This disparity (as well as the one estimated for education expectations alone) is greater than that usually reported between high-school graduates and dropouts, which has typically been taken to be the most useful indicator of poor potential. But dropouts now make up only a small fraction of enlistees. Attrition indicators with similar discriminative power for seniors and graduates should thus be of great utility for targeting and predictive purposes.

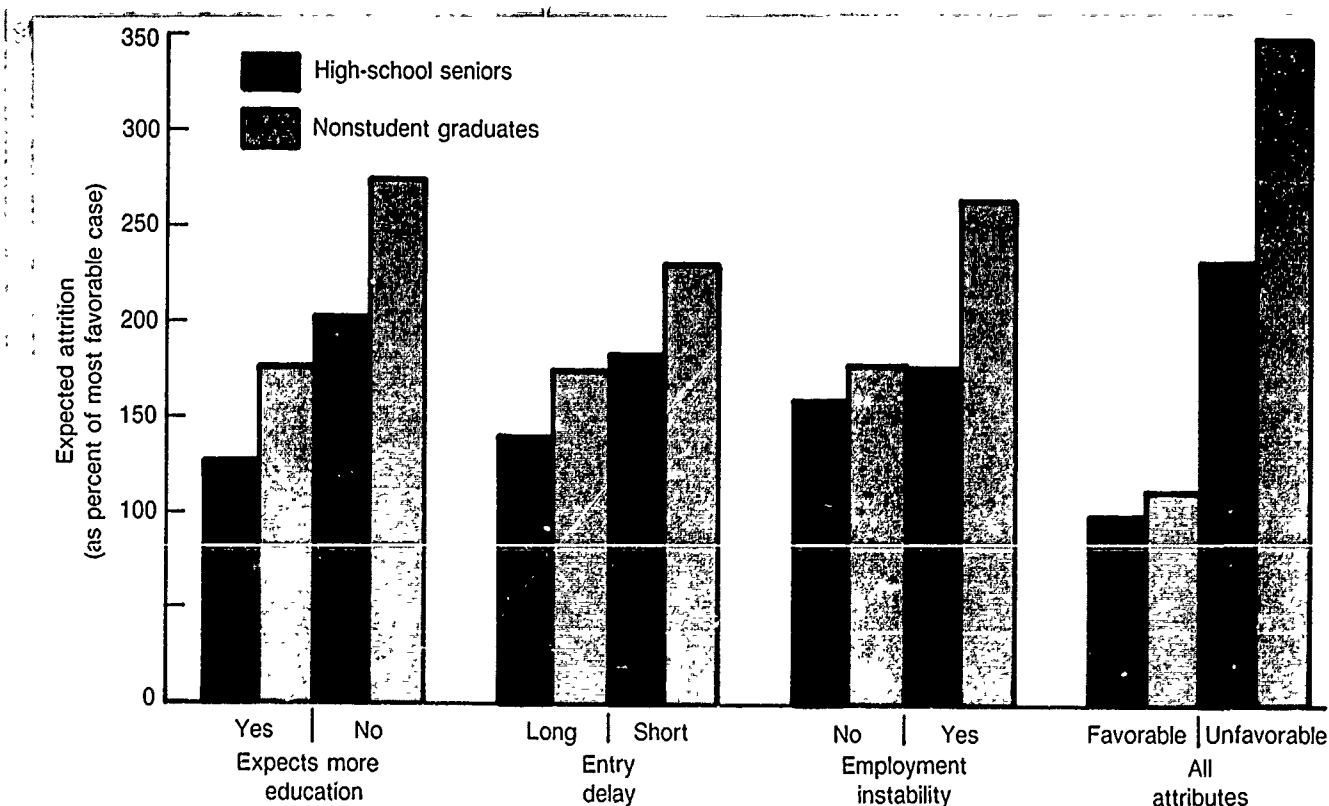


Figure 17
Effects of single and multiple attributes on attrition

In any analysis such as this, there is the possibility that some significant determinants may not have been accounted for. For example, no attempt was made to quantify "taste" for military life. The analytical framework did, however, allow an estimate to be made of any correlation between factors omitted from the enlistment assessment and those left out of the attrition

model. No such correlation was found. That suggests that the Center's model can be used to predict attrition in a cohort or individual without worrying about what characteristics the enlistment process may have selected for; in other words, the attrition model is equally applicable to cohorts with varying attributes at enlistment.

Research Highlight

ANALYZING THE COST OF RESERVE FORCE CHANGES

Congress and the Administration have increasingly come to view the Reserve force as a cost-effective complement to the Active force. As a result, the number of National Guard and Reserve units and personnel has been increasing. Other force changes have sprung from the practice of arming Reserve force units with weapon systems being phased out of the Active force. Such additions and other changes entail costs whose measurement would facilitate force planning.

John F. Schank, Susan J. Bodilly, and their colleagues at NDRI's Defense Manpower Research Center have performed a number of illustrative cost estimates of Reserve force changes to permit a better understanding of the variables involved.¹ Their approach addresses both the one-time, nonrecurring costs of change and the subsequent recurring operating and support costs required. It also raises the issue of secondary costs to units other than those directly affected by the change.

The RAND analysts identified four categories of **one-time costs** when a new unit is activated or an old one is reequipped: construction of additional facilities, procurement of unit equipment, personnel acquisition, and training to meet special skill requirements. The research team examined 15 varied instances of unit change in Air Force and Navy Reserve components. These case studies demonstrated the importance of each of the cost categories but did not permit broad conclusions regarding costs or cost savings to be drawn.

¹See R-3210-RA, *Unit Cost Analysis: Annual Recurring Operating and Support Cost Methodology*, and R-3210/1-RA, *Unit Cost Analysis: Executive Briefing*, John F. Schank, Susan J. Bodilly, and Richard Y. Pei, March 1986; and R-3492-RA, *Cost Analysis of Reserve Force Change. Non-Recurring Costs and Secondary Cost Effects*, John F. Schank, Susan J. Bodilly, and A. Allen Barbour, May 1987.

Of course, the one-time costs of creating a new Reserve force unit could be reduced by locating it on an Active base with excess capacity. But in general, nonrecurring costs are highly sensitive to the special circumstances attending each change.

The analysts developed equations for calculating **recurring operating and support costs**. The latter comprise personnel acquisition and training costs and the costs of consumable items such as spare parts, training ordnance, and petroleum, oil, and lubricants. Case studies showed how the difference in recurring costs between analogous Reserve and Active force units depends on the capital-intensiveness of the units. An infantry unit could be operated for a fraction of the cost in the Reserve force, but savings are much less for an airlift or a frigate unit.

Case studies also demonstrated the dominance of recurring costs over one-time costs, particularly for capital-intensive units. If, in reequipping a Reserve force unit, operating and support costs are reduced, initial one-time expenditures might be recouped in a matter of a few years.

The cost effects of a unit change can extend beyond the Reserve force unit directly involved. Weapon systems or other equipment no longer needed by a reequipped unit may be moved to another unit, affecting costs there. If an Active-to-Reserve equipment transfer is intended to support a mission transfer, the cost savings to the total force may not be realized if the Reserve unit cannot fully accomplish the mission. The Center's cost paradigm recommends incorporating such secondary costs insofar as they fall within the scope of the decision under consideration.

Work on unit cost analysis continues at NDRI. Center staff have developed a detailed accounting system that will be incorporated into both a handbook and a micro-computer model for assessing the costs of changes in the Active/Reserve balance.

Research Highlight

EVALUATING THE CHAMPUS REFORM INITIATIVE

The dependents of Active-duty personnel and members of military retirees' families receive health care from military treatment facilities and from civilian providers reimbursed through the Civilian Health and Medical Program of the Uniformed Services (CHAMPUS). CHAMPUS resembles a traditional health insurance plan. Beneficiaries pay some of the costs of care, and a wide range of services is covered. Like other health insurance programs, CHAMPUS has experienced rapidly increasing costs. In addition, beneficiaries responding to surveys have expressed dissatisfaction with access to care, continuity of care, benefits, and paperwork.

In an effort to correct CHAMPUS's problems, the Assistant Secretary of Defense (Health Affairs) has developed a set of reforms. Congress has requested that the reforms be given a limited demonstration before being implemented nationwide. A team of RAND researchers led by Susan D. Hosek will monitor the demonstration's execution, estimate the effectiveness of the reforms, and suggest any changes in the reforms that appear to be warranted.¹

Under the CHAMPUS Reform Initiative, a contract covering all CHAMPUS services in a given geographical area will be let for a fixed price. The contractor will establish a network of "preferred" health care providers. Beneficiaries limiting their provider choice to that network will be offered increased primary-care coverage and decreased cost-sharing. The contractor will also be required to establish the following:

- A "Healthcare Finder" service to help beneficiaries obtain appointments, referrals, and record transfers.

¹For a full description of the RAND evaluation, see N-2647-HA, *Plan for an Evaluation of the CHAMPUS Reform Initiative*, Susan D. Hosek et al., July 1987.

- "Resource sharing" agreements with local military hospitals, intended to allow the hospitals to accept patients they can treat more efficiently.
- Quality assurance and utilization review programs to make sure that quality of care is maintained while unnecessary procedures are avoided.

The Assistant Secretary hopes to improve coordination between the military facilities and the CHAMPUS providers, enhance services for beneficiaries, and contain costs. To determine whether the reform initiative will achieve those objectives, the RAND team will measure changes over the course of the demonstration in a number of key variables:

- Beneficiary use of military treatment facilities and CHAMPUS services.
- Beneficiary and government costs.
- Quality of care.
- Access to care.
- Continuity of care.
- Administrative simplicity for beneficiaries.
- Beneficiary satisfaction.

To separate changes brought on by the reforms from changes caused by other factors, those variables will be measured not only in the demonstration area (California and Hawaii) but also in other localities.

As the demonstration is being set up, RAND will review the methods used, the schedules followed, problems encountered, and ways in which the problems are solved. The lessons learned in this review will be useful in implementing the reforms elsewhere.

Given the complexity of the reform initiative and the tendency of institutions and people to change only slowly, the effects of the initiative are not likely to be fully felt over the course of the demonstration. RAND's conclusions and recommendations will recognize the possibility of additional responses on the part of health care providers and beneficiaries.

